ELECTRONIC PROCUREMENT ADOPTION FOR CONSTRUCTION PROJECTS IN GHANA: MODEL DEVELOPMENT FOR THE INFLUENTIAL ISSUES

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Electronic Procurement Adoption for Construction Projects in Ghana: Model Development for the Influential Issues

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CERTIFICATE OF ORIGINATLITY

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___________________ (Signed)

Sitsofe Kwame Yevu (Name of student)

DEDICATION

I dedicate this thesis to God Almighty, Jesus Christ and the Holy Spirit for the provision of grace, strength, protection, inspiration and direction to successfully undertake this study. Also, I dedicate this thesis to my wife and son for their support and prayers, and to my parents and siblings for the encouragements and sacrifices.

ABSTRACT

The digital evolution of procurement activities in the construction industry through electronic procurement systems (EPSs), has been essential in improving efficiency and facilitating sustainable construction globally. EPSs refer to the use of online or web-based systems to digitize and automate procurement processes/activities at various stages of construction projects. Over the past two decades, several governments and industry agencies have made efforts to transform construction procurement (CP), since CP offers a vital artery in the delivery of projects and an avenue to facilitate construction's fourth revolution. However, the adoption and use of EPSs in CP is influenced by various influential issues that are webbed in complexity, making its implementation difficult in project environments. To effectively accelerate EPSs implementation in CP, it is important to understand the influential issues in their adoption, especially from the developing economies context.

This study aims to examine the complex issues influencing EPSs uptake in construction projects. Accordingly, five objectives were developed: (1) to identify the important EPSs benefit drivers and to examine the influences of the benefit drivers in EPSs adoption process in Ghana; (2) to identify quantifiable EPSs benefit drivers for evaluation in Ghana; (3) to identify the critical barriers to EPSs implementation in construction procurement and model their influential relationship patterns on EPSs uptake in Ghana; (4) to determine the important strategies for EPSs implementation and evaluate their synergistic influences in the promotion of EPSs implementation in Ghana; and (5) to develop an implementation model based on the results of this study, to aid in the promotion and implementation of EPSs in the construction industry in Ghana. Though, EPSs implementation have gained traction in past studies, the

complex synergistic influences of these issues are scarce and studies addressing the developing economies context, including Ghana, are inadequate.

The study's objectives were achieved through multistage processes involving comprehensive literature reviews and surveys with procurement practitioners having experience in EPSs implementation. The data were analyzed using different quantitative analytical techniques. Concerning EPSs benefit drivers, the benefit groups with significant influential forces when combined, to create a suitable environment are related to – integrity and environment, process optimization, fairness and conformance, information integration, client and smart resource system. Although, all the benefit groups obtained high influence levels in the fuzzy model, the driving forces with relatively higher weights were integrity and environment-related forces and process optimization-related forces. Regarding quantitative evaluation of EPSs benefits based on the priority model, effective monitoring of process (real time), reducing cycle times for process and transaction, enhancing regulatory compliance on contracts, improved communication with stakeholders, client satisfaction and access to internet intelligent tools for decision-making, were preferred from the respective benefit groups for quantitative assessments.

On the influences of barriers to EPSs, five underlying barriers were identified; human-related barriers, technological risk-related barriers, government-related barriers, industry growth-related barriers and financial-related barriers. By applying the neuro-fuzzy model, various influence patterns of the barriers were identified, with addressing human-related barriers and technological risk-related barriers/government-related barriers being a key path of reducing the hindrance to EPSs implementation. For the strategies promoting EPSs implementation, five clusters of strategies were derived; technology education, innovation culture management, technology stimulation environment, incentives and partnerships mechanisms and

organizational integration support. Hybrid-approaches for combining the strategies were derived and how their application could be optimized in project situations for effective promotion of EPSs in project environments were established using the neuro-fuzzy model.

In consolidating the study's findings, an implementation system model was developed to facilitate the widespread use of EPSs in Ghana considering the variabilities in project environments. Further, the implementation system model was validated by industry practitioners for credibility, practicality and reliability. This study makes valuable contributions to EPSs literature, especially on the dynamic influence relationships among the influential issues of EPSs adoption in construction projects. The added value of the study does not only lie in aiding researchers and policy makers to understand the complexities of issues influencing EPSs uptake, but also to encourage practitioners for widespread implementation of EPSs in Ghana.

Keywords: Electronic procurement systems; Drivers; Benefits; Barriers; Strategies; Construction procurement; Construction industry; Developing countries.

LIST OF RESEARCH PUBLICATIONS

The following provides the list of research publications produced in this study and chapters in this study have been fully or partially published in these publications.

A. Refereed Journal Papers (published/ accepted) (2018 – 2021)

1. **Yevu S. K.,** Yu A. T. W., Darko A., and Addy M. N. (2021). Evaluation model for influences of driving forces for electronic procurement systems application in construction projects. *Journal of Construction Engineering and Management*. *147*(8), 04021076.

2. **Yevu, S. K.,** Yu, A. T. W., Nani, G., Darko, A., and Tetteh, M. O. (2021). Electronic procurement systems in construction procurement: Global experiences of barriers and strategies. *Journal of Construction Engineering and Management*. Manuscript ID: COENG-11130R1(in press).

3. **Yevu S. K.,** Yu A. T. W., Darko A. (2021). Digitalization of construction supply chain and procurement in the built environment: Emerging technologies and opportunities for sustainable processes. *Journal of Cleaner Production*. Manuscript ID: JCLEPRO-D-21-12092R1(in press)

4. **Yevu, S. K.,** Yu, A. T. W., and Darko, A. (2021). Barriers to Electronic Procurement Adoption in the Construction Industry: A Systematic Review and Interrelationships. *International Journal of Construction Management*. 1-15.

5. Yu, A. T. W., **Yevu, S. K.,** and Nani, G. (2020). Towards an integration framework for promoting electronic procurement and sustainable procurement in the construction industry: A systematic literature review. *Journal of Cleaner Production*, 250, 119493.

6. **Yevu, S. K.** and Yu, A. T. W. (2020). The ecosystem of drivers for electronic procurement adoption for construction project procurement: A systematic review and future research directions. *Engineering, Construction and Architectural Management*, *27*(2), 411-440.

7. **Yevu, S. K.,** Yu, A. T., Tetteh, M. O., and Antwi-Afari, M. F. (2020). Analytical methods for information technology benefits in the built environment: towards an integration model. *International Journal of Construction Management*, 1-12.

B. Refereed Journal Papers (under review for the first or second time)

1. **<u>Yevu S. K.,</u>** Yu A. T. W., Adinyira, E., Darko A., Antwi-Afari, M. F. (Under review). Optimizing the application of strategies promoting electronic procurement systems towards sustainable construction in the building lifecycle: A neurofuzzy model approach. *Journal of Cleaner Production*. Manuscript ID: JCLEPRO-D-20-25572R1

2. **<u>Yevu S. K.,</u>** Yu A. T. W., Darko A., and Nani, G. (Under review). Modeling the influence patterns of barriers to electronic procurement technologies usage in construction projects. *Engineering, Construction and Architectural Management*. Manuscript ID: ECAM-01-2021-0013

C. Other Journal Papers

1. Antwi-Afari, M. F., Li, H., Anwer, S., **<u>Yevu, S. K</u>**., Wu, Z., Antwi-Afari, P., and Kim, I. (2020). Quantifying workers' gait patterns to identify safety hazards in construction using a wearable insole pressure system. *Safety science*, 129, 104855.

2. Antwi-Afari, M. F., Li, H., Seo, J., Anwer, S., **<u>Yevu, S. K.,</u>** and Wu, Z. (2020). Validity and reliability of a wearable insole pressure system for measuring gait parameters to identify safety hazards in construction. *Engineering, Construction and Architectural Management*. *28*(6), 1761-1779.

3. Tetteh, M. O., Chan, A. P. C., Effah, Ameyaw, E. E., Darko, A., **<u>Yevu, S. K.</u>**, and Boateng, E. B. (2020). Management control structures and performance implications in international construction joint ventures: critical survey and conceptual framework. *Engineering, Construction and Architectural Management*. DOI 10.1108/ECAM-07-2020-0579

4. Tetteh, M. O., Chan, A. P. C., Darko, A., **<u>Yevu, S. K.,</u>** Boateng, E. B., Nwaogu, J. M., (2020). Key drivers for implementing international construction joint ventures (ICJVs): Global insights for sustainable growth. *Engineering, Construction and Architectural Management*. Manuscript ID: DOI 10.1108/ECAM-07-2020-0512

D. Refereed Conference Paper

1. **<u>Yevu, S. K.</u>** and Yu, A. T. W. (2019). Electronic Procurement Adoption in the Construction Industry: A Critical Review of Literature. *CIB World Building Congress, Constructing Smart Cities*, Hong Kong Polytechnic University, Hong Kong.

2. **<u>Yevu, S. K</u>**<u>.,</u> Yu, A.T.W. and A. Darko (2020). Predicting the impact of distributed ledger technology on electronic procurement processes in the built environment, Construction and building Research (COBRA) at ARES 2020 Conference. Florida, USA.

3. **<u>Yevu, S. K.,</u>** Yu, A. T. W., Darko, A., and Tetteh, M. O. (2021). Key factors for electronic procurement systems in the promotion of sustainable procurement in construction projects. West African Built Environment Research (WABER) Conference, August, 2021, Accra, Ghana.

E. Refereed Journal Papers (Pending submission)

1. **<u>Yevu, S. K.,</u>** Yu, A. T. W, Darko, A., Antwi-Afari, M. F., Tetteh, M. O. Drivers for digitizing construction procurement: An international experts experience for electronic procurement systems.

2. **<u>Yevu, S. K.</u>** and Yu, A. T. W. Electronic Procurement Research for Construction Infrastructure Projects: A Review of Literature.

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LIST OF ABBREVIATIONS

AHP	-	Analytic Hierarchy Process
AI	-	Artificial Intelligence
ANFIS	-	Adaptive neuro-fuzzy inference system
ANN	-	Artificial Neural Network
BG	-	Barrier group
CDF	-	Critical driving force
CP	-	Construction procurement
DF	-	Driving Force
DOI	-	Diffusion of innovation
EFA	-	Exploratory factor analysis
EPSs	-	Electronic Procurement Systems
EU	-	European Union
FA	-	Factor analysis
FIS	-	Fuzzy inference system
FRB	-	Financial-related barriers
FSE	-	Fuzzy synthetic evaluation
GCI	-	Ghanaian construction industry
GDP	-	Gross Domestic Products
GIIF	-	Ghana Infrastructure Investment Fund
GoG	-	Government of Ghana
GSS	-	Ghana Statistical Service
GZ	-	Group zone
HL	-	Hindrance level

HRB	-	Human-related barriers
ICM	-	Innovation culture management
IGRB	-	Industry growth-related barriers
IOS	-	Interorganizational systems
IPM	-	Incentives and partnerships mechanisms
ISSER	-	Institute of Statistical, Social and Economics Research
IV	-	Input variables
KMO	-	Kaiser-Meyer-Olkin
LPE	-	Learning parameters element
LSE	-	Learning structure element
MAPE	-	Mean absolute percentage error
MF	-	Membership function
MPE	-	Mean percentage error
MV	-	Mean values
NFS	-	Neuro-fuzzy systems
OECD	-	Organization for Economic Co-operation and Development
OIS	-	Organizational integration support
OV	-	Output variable
PC	-	Project case
PCFA	-	Principal component factor analysis
PDF	-	Principal driving force
RMSE	-	Root-mean-square error
RRB	-	Regulation-related barriers
SC	-	Strategies clusters

SD	-	Standard deviation
SDGs	-	Sustainable Development Goals
SPSS	-	Statistical Package for Social Science
TE	-	Technology education
TIL	-	Total influence level
TOE	-	Technology organization environment
TRRB	-	Technological risk-related barriers
TSE	-	Technology stimulation environment
UN	-	United Nations
UNDP	-	United Nations Development Programme
UNPPH	-	United Nations Procurement Practitioner’s Handbook

CHAPTER 1 INTRODUCTION[1]

1.1 INTRODUCTION

The construction industry has been a major contributor to national economies and a facilitator of sustainable developments in other industries through job creation and procurement of construction products and services (Abdul Nabi and El-adaway, 2020; Le et al., 2014; Santoso and Bourpanus, 2019). With contributions of 10-40% to gross domestic products (GDP) in national economies globally (Chiang et al., 2015; Anumba and Ruikar, 2002), the construction industry has been long criticized for its ineffectiveness and inefficiencies towards improving project processes, enhancing sustainability and embracing innovative technologies (Townsend and Gershon, 2020; Ibem and Laryea, 2017). In the construction industry, procurement processes initiate and determine a project's spending and the selection of resources, which in turn, influences economic developments with social and environmental implications (Yu et al., 2020; Walker and Brammer, 2012). Construction procurement (CP) processes/activities for a project are multifaceted, intensive and occurs at various stages of a project lifecycle (Grilo and Jardim-Goncalves, 2011), hence, complex interactions from multidisciplinary construction

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[1] This chapter is largely based on:

Yevu S. K., Yu A. T. W., Darko A., and Addy, M. N. (2021a). Evaluation model for influences of driving forces for electronic procurement systems application in construction projects. *Journal of Construction Engineering and Management*. *147*(8), 04021076.

Yevu, S. K., Yu, A. T. W., Nani, G., Darko, A., and Tetteh, M. O. (2021d). Electronic procurement systems in construction procurement: Global experiences of barriers and strategies. *Journal of Construction Engineering and Management*. Manuscript ID: COENG-11130R1(in press).

Yevu, S. K., Yu, A. T. W., and Darko, A. (2021b). Barriers to Electronic Procurement Adoption in the Construction Industry: A Systematic Review and Interrelationships. *International Journal of Construction Management*. 1-15.

Yu, A. T. W., Yevu, S. K., and Nani, G. (2020). Towards an integration framework for promoting electronic procurement and sustainable procurement in the construction industry: A systematic literature review. *Journal of Cleaner Production*, *250*, 119493.

Yevu, S. K., and Yu, A. T. W. (2020). The ecosystem of drivers for electronic procurement adoption for construction project procurement. *Engineering, Construction and Architectural Management*, *27*(2), 411-440.

Yevu, S. K., Yu, A. T., Tetteh, M. O., and Antwi-Afari, M. F. (2020). Analytical methods for information technology benefits in the built environment: towards an integration model. *International Journal of Construction Management*, 1-12.

professionals are involved in the process. The activities and complex interactions in CP using the manual paper-based method makes CP susceptible to weaknesses including prolonged timelines, increased process cost and ineffective use of procurement resources (Aibinu and Al-Lawati, 2010).

Considering the resources and high capital expended on projects, CP has received much attention from both public agencies and industry practitioners, with the quest of ensuring efficiency and effectiveness in procurement processes (Yevu et al., 2021e). As a result, electronic procurement systems (EPSs) were introduced into CP to mitigate the weaknesses of the manual paper-based method and improve efficiency (Mehrbod and Grilo, 2018; Ajam et al., 2010; Pala et al., 2016). Conventional experience with the use of manual paper-based methods for CP activities indicates that its inherent limitations created problems pertaining to errors, transparency and long processing times. Therefore, studies such as Nitithamyong and Skibniewski (2007) indicated that the uptake of EPSs could be used to tackle the issues of the manual paper-based method. Although, the uptake of EPSs for CP has been generally slow in many construction industries, Eadie et al. (2010a) emphasized that contextual understanding of the particular country aids in the promotion and adoption of the EPS technology. Furthermore, Tan et al. (2021) highlighted that the successful application of digital technologies in construction projects heavily depends on the issues in the project environment. To this end, particularly in developing countries, considering their increasing need for more infrastructure projects to sustain economic development, governments, researchers and practitioners have to understand the contextual complexities and nuances to ensure optimized benefits from EPSs application. While EPSs promises numerous benefits for CP, there still exist hindrances to their widespread promotion and adoption in the construction industry.

Hence, this research study attempts to address these issues from the perspective of developing countries.

1.2 BACKGROUND STUDY

The construction industry, which is characterised by high fragmentation, less effective communication, temporal project-based approaches and increasing project complexity, requires different types of information from various stakeholders for CP processes and supply chain (Cheng et al., 2010; Khan et al., 2016). The procurement process starts with the need for acquiring projects and continues throughout the lifecycle of the project including the pre-contract and post-contract stages (Costa and Tavares, 2013). In these processes, multiple stakeholders including project managers, architects, quantity surveyors, engineers and contractors exchange procurement-related information, which in turn determines the services, project cost, resources, procedures and materials to be used on the project. Hence, the procurement process makes available the necessary requirements needed for several components/aspects of projects to be completed (Naoum and Egbu, 2016).

The activities of CP range from the identification of need regarding construction products, works and services to their delivery. In turn, CP becomes the channel that accounts for huge expenditures on projects (Costa et al., 2013). History suggests that CP processes (e.g. contractor selection process) for projects have been conducted using the traditional method, i.e. manual paper-based method over the past decades (Anumba and Ruikar, 2002; Ajam et al., 2010). The manual paper-based method focuses on using paper documentation and physical interactions for information exchange at various stages of the CP process (Ibem and Laryea, 2017). However, the manual paper-based method has been identified over the years to be inefficient and ineffective since it is beleaguered with high cost of process, time delays, labour intensity, high error margins, bulky storage and slow rate of information exchange among project parties (Lou and Alshawi, 2009; Nawi et al., 2017). These problems of the manual paper-based approach to procurement have resulted in low productivity and untimely flow of information to project participants which affects the project performance and increases the tendency of disputes (Santoso and Bourpanus, 2019; Zou and Seo, 2006). The need to overcome the shortcomings of the manual paper-based method and improve efficiency in CP led to the introduction of EPSs amidst the drive for digitalization towards construction's revolution.

The active emergence and usage of internet technology in the twenty-first century urged government agencies, international organizations and construction professionals to increase competitive advantage by digitally transforming the processes/practices in the construction industry (Ruikar et al., 2006). CP is one sector in the construction industry which has been identified for such transformation, that is, changing from the paper-based method to EPSs (Eadie et al., 2011). EPSs uses online technologies and platforms to manage the CP process which brings numerous benefits that addresses the limitations of the manual paper-based method (Doloi, 2014; Mehrbod and Grilo, 2018). Benefits such as cost and time reduction and transparency have motivated the uptake of EPSs to streamline and integrate the flow of information by public agencies and construction stakeholders (Yevu and Yu, 2020).

Despite the benefits of EPSs, its uptake has been slow and has suffered many setbacks in various construction industries globally (Jacobsson et al., 2017; Adriaanse et al., 2010). This could be attributed to the construction industry's conservative nature in presenting certain complex challenges to the widespread adoption of EPSs technological innovations in project environments (Ajam et al., 2010). As a result, the anticipated benefits of EPSs from its widespread uptake are not effectively realized (Wimalasena and Gunatilake, 2018; Yevu et al., 2021a). Therefore, there have been some attempts from past studies in understanding EPSs uptake mostly from the developed economies context. Since the local construction conditions, economic and social issues specific to a country's context influences the rate of adopting EPSs, the problem is, which factors/issues within a country's construction industry influence the uptake of EPSs from developing economies context. An understanding of the peculiar issues in a particular construction industry is needed to promote the wider uptake of EPSs in the respective country. Hence, this research study explores the influences of factors in the process of EPSs adoption in the construction industry, from the context of a developing economy.

1.3 RESEARCH PROBLEM AND SCOPE

With increasing population rates above 12% per year and slower rates of economic growth, most developing economies are challenged with infrastructural issues including lack of housing and health facilities, poor roads and bridges, inadequate water supply and insufficient power supply, which have resulted in poor health, unemployment, poor education and weak security (Ghana Statistical Service (GSS), 2014; United Nations Development Programme (UNDP), 2018). These problems have made developing economies struggle in achieving good progress with the millennium development goals (United Nations (UN), 2000), hence the introduction of sustainable development goals (UN, 2016) presents a more difficult task for developing economies to achieve. The increased rate of population and the request for sustainable economic development have stimulated the need for increasing infrastructural development, which consequently begins and ends with CP processes. CP for infrastructure/building projects in most developing economies has been consistently fraught with ineffectiveness, lack of transparency, overspending, corrupt practices and prolonged process timelines using the manual paper-based method (Anvuur et al., 2006; Osei-Tutu et al., 2010). Hence, the urgent need for the introduction of EPSs into CP processes has been encouraged to improve efficiency, effectiveness and value addition on projects. For a sustained usage of EPSs, knowledge and information on the measures, actions, and strategies needed by governments, policy makers and industry practitioners must be provided, to ensure their efforts support the successful implementation and continual usage of EPSs.

In the case of Ghana (a developing economy in West Africa), the infrastructural development is hindered by similar problems related to socio-economic and construction issues facing other developing countries globally. For instance, the manual paper-based method which has been the primary method of procurement in Ghana for decades (Ameyaw et al., 2012), is known for lengthening activities at the pre-contract stage resulting in delays for project delivery and raising contractual disputes, and in some circumstances stalling projects due to procurement malpractices. The Ghanaian construction industry (GCI) is a major contributor to the national economy, and construction activities generated about US$ 3.8 billion in 2014 which represents about 12% of GDP and provided over 2% of direct employment to the youth (GSS, 2016). Further, the average share of the GCI with regard to national investments is about 30% (Institute of Statistical, Social and Economics Research (ISSER), 2013). This indicates that CP which initiates these construction projects investments within the GCI is a critical sector for improving expenditure, value and project delivery. Considering the huge infrastructure gap of about US$1.5 billion over the next decade (World Bank, 2012), achieving efficiency and effectiveness in CP has become a necessity in order to avoid wasting financial and other valuable resources. Within the Ghanaian local context, the manual paper-based method creates many mistakes, thereby increasing the rate of contractual disputes and reducing the level of reliability and transparency of the CP processes for projects. Since, 50% of the government's expenditure is procurement related in Ghana, the low quality of process and lack of competitiveness consistently besetting CP, creates problems for practitioners (World Bank, 2015). These shortfalls of the manual paper-based method present huge hindrances to improving efficiency and effectiveness on CP process in the GCI for a sustainable economic growth (Yevu and Yu, 2019). Considering these issues, the need for EPSs to provide sustainable solutions in CP is more evident in Ghana.

The implementation of EPSs has been shown to bring many benefits to CP and overcome the limitations of the manual paper-based method. For example, organizations using EPSs experienced about 11% reduction in administrative costs and the improved audit trail benefit increased the transparency of the process (Alshawi and Ingirige, 2003; Svidronova and Mikus, 2015). In the past, several studies explored the implementation of EPSs from the perspectives of developed economies including the UK, the US, Australia, Hong Kong and Portugal (Gunasekaran and Ngai, 2008; Eadie et al., 2012; Doloi, 2014; Costa and Tavares, 2013). However, the perspectives of developing economies with different socio-economic settings as compared to developed countries are scarce in literature. This scarcity creates a gap in EPSs research regarding developing economies, and its palpable as developing economies are yet to widely adopt EPSs in their construction industries. Further, this research gap is deepened as studies from the developed economies on EPSs research neglected the complex interactions of influential issues such as the barrier factors in evaluating EPSs uptake. The lack of knowledge on the interactions among the factors of these influential issues in EPSs research contribute to the slow rate of EPSs adoption. This is because, knowledge on the dynamic patterns of how these issues influence EPSs is limited. To that effect, an understanding of the interactions among the factors of the key influential issues (e.g. challenges and strategies) could provide vital and novel insights of the synergistic effects required for effective acceleration of EPSs uptake in the construction industry.

Like some few developing countries, Ghana has also expressed interest in adopting EPSs for CP processes on projects (IEG-World Bank Report, 2016). After 2009, initial discussions from public agencies on the adoption of EPSs for CP began with the aim of enhancing transparency, fairness, effectiveness, efficiency and faster processing time (Public Procurement Authority, 2010). In the past, several EPSs implementation attempts were unsuccessful, however, recently, some organizations have introduced EPSs in their CP for projects. Despite these developments, empirical research on the main contextual issues such as the driving forces, barriers and strategies influencing EPSs adoption in the GCI is lacking. For instance, the influences of EPSs benefits have been identified as a key force in motivating construction practitioners to use EPSs (Doloi, 2014), however, the desired quantification of EPSs benefits realized presents a multidimensional problem for construction practitioners (Yevu et al., 2020). Further, the lack of models effectively evaluating EPSs implementation issues raises challenges for policy-makers and practitioners in determining productive approaches for a sustained usage of EPSs in CP. Such a study is important because previous studies have revealed that the successful adoption and implementation of EPSs for construction depends on the understanding and developments gotten from the local context (i.e. Ghana) while integrating appropriate measures from best international practices (Eadie et al., 2010a; Wimalasena and Gunatilake, 2018). This gives the cause for a comprehensive investigation into the influential issues of adopting EPSs and how EPSs adoption can be accelerated among construction organizations in the construction industry.

1.3.1 Research questions

The research gaps in extant EPSs literature regarding the influences and interactions of issues determining the uptake and usage of EPSs, raises questions pertaining to:

1. What are the significant benefits of EPSs driving their adoption in the construction industry in Ghana?
2. What benefits of EPSs are important for quantitative assessment in the GCI regarding benefit realization evaluation?
3. What are the critical barriers to EPS uptake and how do they influence EPSs implementation in Ghana?
4. What are the important strategies that promote EPSs and what effects do they have in facilitating EPSs uptake in GCI?

1.3.2 Research Scope

This research study primarily focuses on examining the main issues influencing the implementation of EPSs in CP for projects in the GCI. The study adopts the fuzzy logic and neural networks to determine the influence levels of these issues on EPSs from CP practitioners in Ghana. The implementation of EPSs depends on the local context, hence, research exploring the influential factors in EPSs implementation in the Ghanaian context paves way for its wider adoption in the GCI. In this study, the models to be developed describe systematic implementation approaches based on the modelling outputs of the influential factors in the process of EPSs adoption, to facilitate effective decision-making on promoting EPSs. A model according to Kwakkel and Pruyt (2013) defines a system that evaluates the significant behaviours and interactions of elements to support decision-making within a research domain and impact industrial practice.

1.3.2.1 Why construction procurement processes/activities in Ghana?

In Ghana, the performance and success of a project and its delivery is heavily dependent on the decisions and processes of various CP activities on a project. Typically, CP activities include planning, tendering, price determination, selection of the contractor, project progress monitoring and project payments. To achieve efficiency and effectiveness on projects, usually project/procurement managers have to critically examine CP processes throughout the project cycle, i.e. from project inception to completion. For instance, improving the transparency and quality of the tendering process or project payments is an issue that project stakeholders have to solve in order to ensure confidence from clients and other stakeholders for their resources on the project from the onset. Therefore, exploring the factors that enhance EPSs adoption for CP activities on projects is necessary.

The adoption process for EPSs in GCI has been slow among construction organizations. However, recently, the government has attempted EPSs for some few construction projects in the country. Currently, the Ghanaian government's main attention is on automating the tendering and contract administration processes for projects which has widely gained popularity for generating numerous CP-related problems consistently over the years on projects (Anvuur et al., 2006; Osei-Tutu et al., 2010). Hence, some EPSs tools are being initiated on selected projects to conduct tendering/bidding and progress payment monitoring functions. However, researchers have stated that there are several areas that require further in-depth research to inform policy-makers and industry practitioners to promote the widespread adoption of EPSs in Ghana (Ameyaw et al., 2012). These areas include the benefits, challenges and promotion strategies for widespread use of EPSs.

In a developing economy like Ghana, various factors such as the lack of a security and the lack of trust have hindered EPSs implementation. Nonetheless, a review of literature, local policies and projects revealed that evaluation models on the contextual issues influencing the widespread use of EPSs in CP activities is lacking, and is yet to be given attention from researchers and practitioners. Given the rising need for infrastructure and the gradual permeation of EPSs to increase digitization in the construction industry, a study examining the influential factors for EPSs is therefore deemed to be crucial and timely for the development of policies and strategies that enhance its success and prevent it from failure. Considering that previous studies highlight the possibility of high failure rate (84%) with information technologies after their introduction in organizations (Altuwaijri and Khorsheed, 2012).

The motivation for this research stems from the fact that EPSs adoption rate have been slow and have suffered many setbacks in the construction industry, particularly in developing countries. Therefore, a study that would evaluate the factors influencing the uptake of EPSs is needed to effectively accelerate the adoption of EPSs in developing countries. The outcome of this study would be beneficial to other developing countries, since the construction industry in Ghana may share similar characteristics with many other developing countries globally. Also, as developing countries account for the lowest share of countries adopting EPSs, this study presents opportunities of accelerating the adoption in these countries with regard to their respective local circumstances.

1.4 RESEARCH AIM AND OBJECTIVES

1.4.1 Research aim

This study aims to develop a model for promoting the use of EPSs for CP processes/activities in the GCI. The following five specific objectives are developed to achieve the overall aim of this study:

1.4.2 Objectives

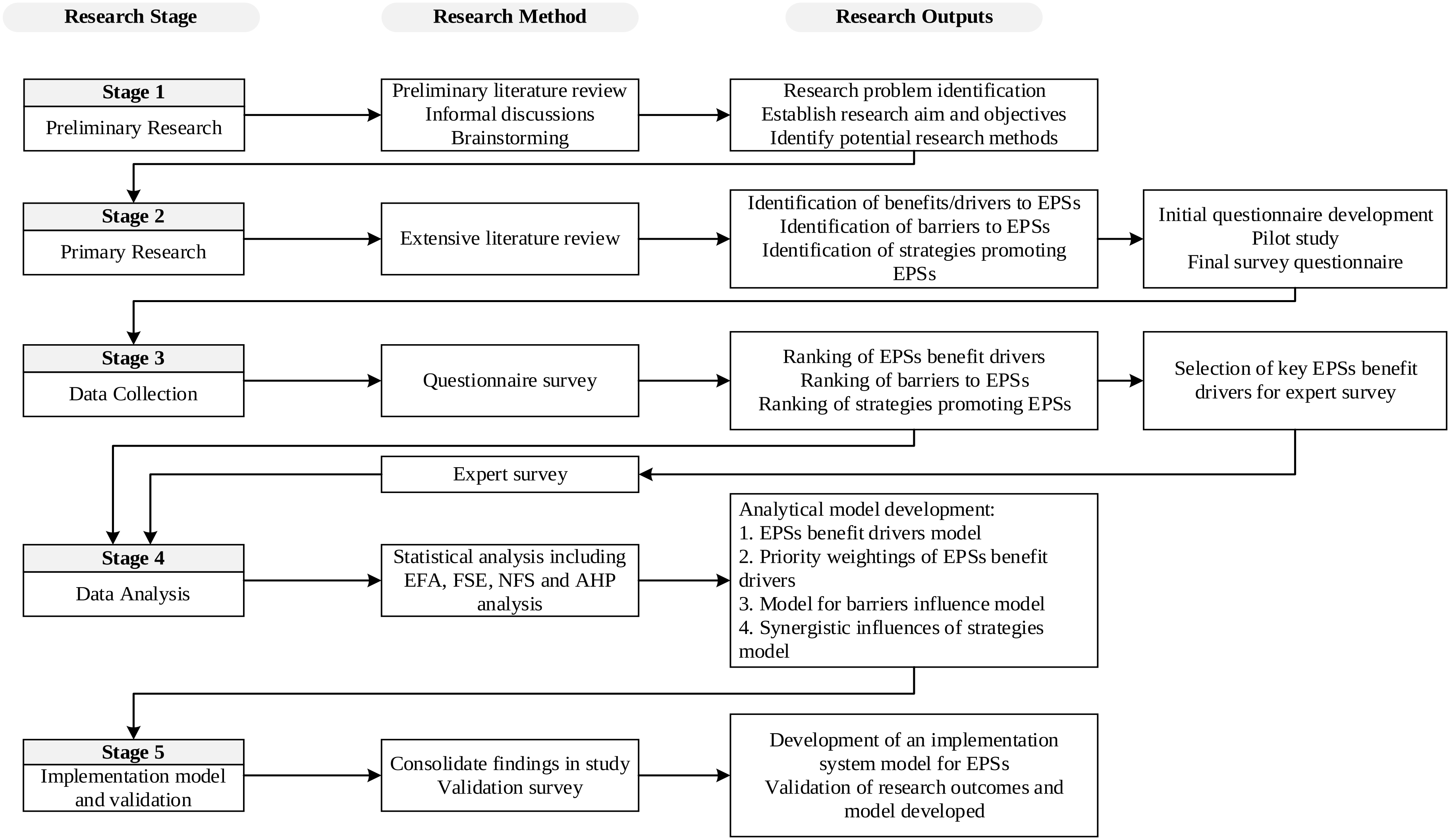
1. To identify the important EPSs benefit drivers and to examine the influences of the benefit drivers in EPSs adoption process in Ghana.
2. To identify quantifiable EPSs benefit drivers for evaluation in Ghana.
3. To identify the critical barriers to EPSs implementation in CP and model their influential relationship patterns to EPSs uptake in Ghana.
4. To determine the important strategies for EPSs implementation and evaluate their synergistic influences in the promotion of EPSs implementation in Ghana.
5. To develop an implementation model based on the results of this study, to aid in the promotion and implementation of EPSs in the construction industry in Ghana.

1.5 RESEARCH METHODOLOGY IN BRIEF

1.5.1 Overall Research Procedure

To achieve the aim and objectives of this study, the research procedures have been detailed systematically in five stages as depicted in Fig. 1.1. Stage 1 assessed the feasibility of the research area through reviewing relevant literature, and thorough discussions with my supervisor and some practitioners and academics in Ghana on the potential of this research area. This preliminary process aided in the identification of the research problem, and the establishment of the research aim and objectives as well as potential methodologies appropriate for the study. Stage two involved conducting a general and extensive literature review related to the objectives of this study. This study covered literature from Ghana and global sources extensively to formulate theoretical foundations for examining EPSs in order to achieve the research aim and objectives. Information sources for the literature review included, journal publications, conference papers, PhD thesis, published reports from organizations, books, internet sources and workshops. In Stage 2, objectives 1, 3 and 4 were partially achieved, that is, the identification of the respective and relevant factors for those objectives.

Stage three focused on the primary data collection through two types of questionnaire surveys (i.e. a general and an expert survey), which included personal interviews with industry experts and practitioners in Ghana. By doing this, objectives 1, 3 and 4 were further stepped forward in their achievement and objective 2 was partially achieved. Stage four entailed the quantitative analysis and the development of models, which aided in the full achievement of objectives 1, 2, 3 and 4, and partial achievement of objective 5. Statistical analysis techniques used for the quantitative analysis included mean scores technique, factor analysis, fuzzy logic, neuro-fuzzy systems (NFS) and Analytic Hierarchy Process (AHP) as explained in Chapter 2. Stage five comprised the development of an implementation model from the findings of the study for validation with EPSs experts. This facilitated the full achievement of objective 5 and the overall aim of the research study.



Note: EFA = Exploratory Factor Analysis; FSE = Fuzzy Synthetic Evaluation; NFS = Neuro-fuzzy System; AHP = Analytic Hierarchical Process.

Fig. 1.1 Overall research procedure for this study

1.6 SIGNIFICANCE AND CONTRIBUTION OF STUDY

This study provides in-depth knowledge and understanding for decision makers and researchers on dynamic influences of issues needed to accelerate EPSs uptake in CP in the construction industry, especially from the developing economies context. The findings from this study provide industry practitioners and policy-makers with effective measures and efforts to ensure rapid adoption of EPSs in construction projects. This study contributes to the body of knowledge with the development of an implementation model that not only provides the quantitative influences of the issues surrounding EPS uptake, but also offers understanding into the interactions of key factors for EPSs adoption. Further, this study provides an insight into how EPSs can be encouraged in construction projects, which contributes and advances the body of knowledge on EPSs implementation in the construction industry.

1.7 STRUCTURE OF THE DISSERTATION

This dissertation is structured in ten chapters. Chapter 1 presents the introduction and background of the research area. Further, it identifies the research problem and formulates research questions that address the gaps in literature. Further, the chapter establishes the research aim, objectives, significance and the methodology adopted in the study. Chapter 2 explains the details of the research methodology. It elaborates on the research design, data collection methods and statistical analytical methods adopted in this study, and the rationale for the selection of the specific methods were provided and justified. Chapter 3 explains the concept of procurement, EPSs, the processes of CP in the construction industry, theoretical underpinnings and the Ghanaian context for EPSs. Chapter 4 focuses on comprehensive analysis of literature to identify the drivers/benefits of EPSs from previous researchers alongside discussions on benefit evaluation. Chapter 5 addresses the barriers affecting EPSs and the strategies promoting the adoption of EPSs. Chapter 6 presents the results and discussions of statistical analysis conducted on the benefit drivers of EPSs, and the benefits preferred for quantitative assessments are also presented in this chapter. Chapter 7 presents the modelling analysis and findings on the influences of barriers to EPSs in the construction industry. Chapter 8, presents the modelling results of important strategies that promote EPS in CP. It is worth mentioning that the results of EPSs benefit drivers, barriers and strategies from the Ghanaian context were compared with other developed economies. Chapter 9 provides and discusses the implementation system model developed for improving EPSs implementation in project environments. Chapter 10 concludes the research study and offers recommendations for future research and practice.

1.8 CHAPTER SUMMARY

This chapter presented the introduction, background, the research problem and research questions for this study. Further, the research aim, objectives, significance and the research approach of this study were presented in this chapter.

CHAPTER 2 RESEARCH METHODOLOGY[2]

2.1 INTRODUCTION

This chapter focuses on the research methodology and systematically discusses the research methods adopted for this study to achieve the research objectives. After outlining the research aim, objectives and scope in Chapter 1, the details and justifications for the selection of the research methods are discussed in this chapter in two parts. The first part expounds on the research methodology, by explaining the rationale for the study's choice of research strategy, followed by the adopted methods and techniques as described in Fig. 1.1, which is subdivided into data collection methods and data analysis methods. The second part presents the background information of respondents in this study. To achieve the research objectives and ensure reliable research findings, selecting the appropriate research methodology is vital (Fellows and Liu, 2015). By selecting and applying research methods that are rigorous and appropriate, construction management research produces meaningful outcomes that contribute significantly to advancing knowledge and industry practice (Walker, 1997). Abowitz and Toole (2010) further emphasized the need for researchers to draw on the knowledge of professional and expert practitioners in the industry when necessary, to enhance reliable outputs of research projects.

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[2] This chapter is largely based upon:

Yevu, S. K., Yu, A. T. W., Darko, A., and Addy, M. N., (2021a). Evaluation model for influences of driving forces for electronic procurement systems application in Ghanaian construction projects. *Journal of Construction Engineering and Management*, *147*(8), 04021076.

Yevu, S. K., Yu, A. T. W., Nani, G., Darko, A., and Tetteh, M. O. (2021d). Electronic procurement systems in construction procurement: Global experiences of barriers and strategies. *Journal of Construction Engineering and Management*. Manuscript ID: COENG-11130R1(in press).

Yevu S. K., Yu A. T. W., Adinyira, E., Darko A., Antwi-Afari, M. F. (Under review). Optimizing the application of strategies promoting electronic procurement systems towards sustainable construction in the building lifecycle: A neurofuzzy model approach. *Journal of Cleaner Production*. Manuscript ID: JCLEPRO-D-20-25572R1

In construction technology-related research, many studies (e.g. Ruikar and Anumba, 2006; Teo et al., 2009; Grilo and Jardim-Goncalves, 2011; Eadie et al., 2012; Costa and Tavares, 2013; Wimalasena and Gunatilake, 2018) have applied different kinds of research methods to examine the benefits/drivers, barriers and strategies pertaining to EPSs implementation in construction projects from various contexts. These methods include literature reviews, case studies, interviews and questionnaire surveys. This research adopted the questionnaire survey as the main data collection tool and supported it with other research methods because surveys offer a wider reach in terms of respondents' participation to understand the extent of a problem. Details of the questionnaire survey development are provided in section 2.4.2. The quantitative approach was mainly used in this research to make measurements of data collected on multiple items. Therefore, the analysis of data collected were carried out using Statistical Package for Social Science (SPSS version 23.0), MATLAB programming environment and the Spreadsheet software. The results were expressed in terms of descriptive means, and factor analysis was used for underlying dimensions of principal components regarding variables. The spreadsheet software was employed for model computations regarding the fuzzy logic application and the AHP prioritization criteria for the benefit drivers of EPSs. The MATLAB programming environment via NFS was used to examine and model the influences of barriers and strategies on EPSs implementation in the construction industry. These methods are discussed in detail in the subsequent sections.

2.2 RESEARCH DESIGN

The design of a research study depends on the nature of the study, the type of data required and the information available (Fellows and Liu, 2015). There are diverse research design paths and frameworks outlined in literature to help researchers conduct research that is relevant and appropriately answers the questions in the research. Researchers can either adopt one design or combine various designs, where it is most appropriate for addressing the problem in the study (Blaike, 2010). The components of the *'research onion'* developed by Saunders et al. (2012) presents a more comprehensive guide for a research design, and hence, it was adopted in this study (see Fig 2.1).

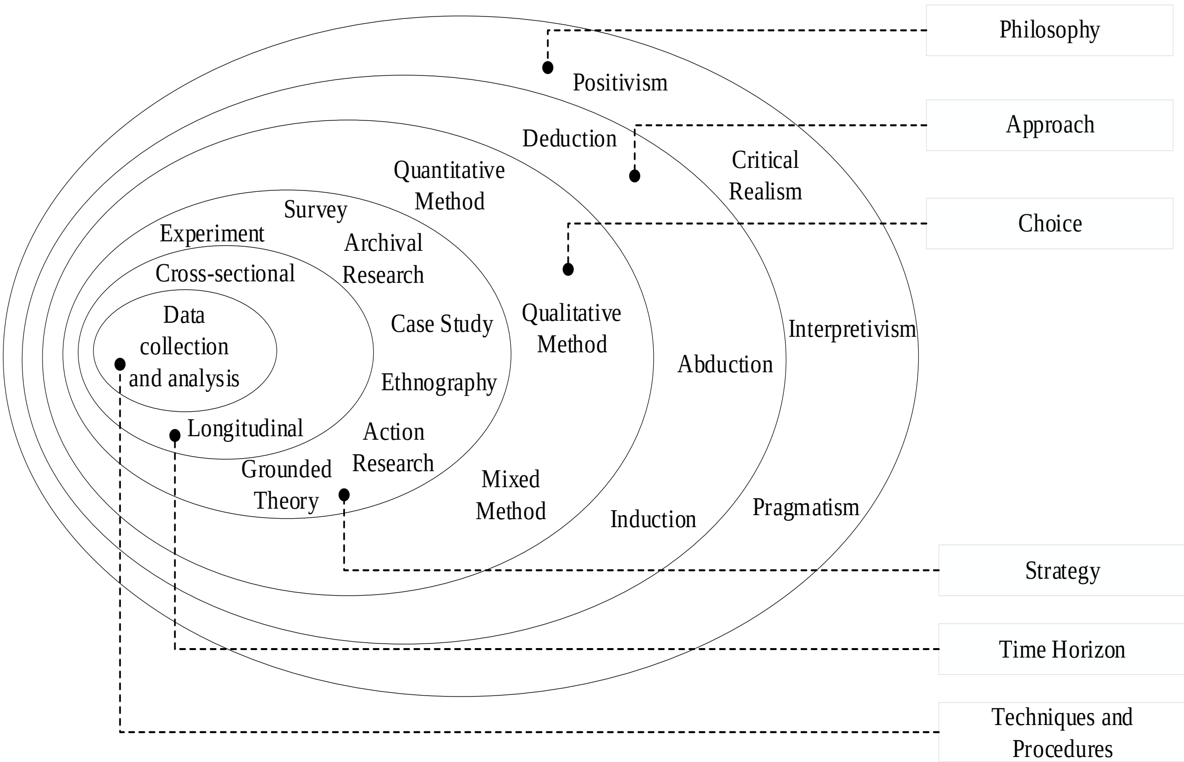

Fig. 2.1 Research onion (adapted from Saunders et al., 2012).

2.2.1 Research philosophy

Research philosophy refers to the set of assumptions underlying the development of knowledge (Saunders et al., 2019). It addresses the beliefs of choosing a research strategy which forms part of a research paradigm. The assumptions of research philosophy are based on ontology, epistemology and axiology. While ontology makes assumptions about the nature of reality, epistemology makes assumptions about what constitutes acceptable and valid knowledge in a particular study area (Burrel and Morgan, 2017). Furthermore, axiology looks at the role of values in the choice of research design and judgement.

On top of this, research paradigms offer researchers with an ideological orientation towards the social world they investigate through the philosophical assumptions. The positivism paradigm refers to the philosophical stance that focus on yielding pure data uninfluenced by human interference and interpretation, hence, it skews towards the objectivist perspective (Fellows and Liu, 2015; Saunders et al., 2019). According to Fleetwood (2005), the critical realism paradigm views reality as independent and external, which cannot be directly accessed through our observation and knowledge of it. For interpretivism paradigm, it is of the view that humans create meaning and they are different from physical phenomena. Therefore, it has a subjectivist perspective. The pragmatism paradigm strives to reconcile dichotomies such as objectivism and subjectivism by considering concepts, theories and ideas not in an abstract form, but in terms of the action roles they play and practical consequences in specific contexts (Elkjaer and Simpson, 2011; Kelemen and Rumens, 2008). Saunders et al. (2019) indicated that with pragmatism, reality is considered as practical effects of ideas and the relevance of knowledge is valued in terms of enabling actions. For pragmatism, problems and questions start the research with the intent of contributing practical solutions that inform future practice (Elkjaer and Simpson, 2011). Pragmatist are interested in practical solutions than abstract distinctions. Thus, the research problem is the most important determinant for research design and strategy.

In this study, which focuses on construction process complexity, the pragmatism research paradigm was adopted due to the complex nature of construction process realities and demand for practical consequences of ideas and experiences. Also, the problem-solving characteristics of construction research, which places value on practical outcomes by applying various methods that are appropriate, influenced the adoption of the pragmatism paradigm.

2.2.2 Research approaches

The foundational approaches of every research study are often clustered into deductive and inductive reasoning, although, reasoning can, alternatively, be abductive (Sekaran, 2003; Saunders et al., 2019). Blaikie (2010) emphasized that deductive reasoning focuses on theory-driven premises. Thus, testing of theories and construction of hypothesis to be examined with empirical data for logical validation or invalidation of existing theories (Fellows and Liu, 2015). In line with this, researchers follow the objective and positivist paths in research. With inductive reasoning, Ketokivi and Mantere (2010) indicated that the researcher observes a phenomenon and arrives at a logical conclusion based on the argument and patterns in the observation. Research using this approach tend to be qualitative with subjective and interpretivist views. However, abduction involves iteration. It combines deduction and induction, i.e. theory-to-data and data-to-theory (Suddaby, 2006; Fellows and Liu, 2015). By complementing the deductive and inductive approaches, the abductive approach begins by observing a problem and finding out relevant theories that could account for what was observed for the testing of logic. From Saunders et al. (2019), the focus of the abductive approach is to modify or incorporate existing theory, where appropriate, for knowledge building in specific contexts.

While the deductive approach is criticized for finite definitions and reductionism, and the inductive approach has setbacks of small samples, the abductive approach offers flexibility to researchers to incorporate several research philosophies that are suitable to the research context. In fact, it is difficult (if not impossible), to achieve pure deduction or induction especially in construction-related settings. Hence, most often in research practice, researchers use some element of abduction. It is important to note that the abductive approach is mostly underpinned by pragmatism, which usually combines quantitative and qualitative (mixed) methods (Creswell, 2014).

The abductive approach is adopted in this study because it is flexible and allows this research to build knowledge by modifying existing theory to suit the observed construction research problem for new theory generation (Saunders et al., 2019). Also, it allows the data to explore the phenomenon to identify themes and patterns. More importantly, since this topic has gained traction in other contexts but has been less studied in the context of the study (Ghana), the abductive approach enables the modification of existing theory for the specific context of practice.

2.2.3 Research method choices

There are three main methodological choices in research; quantitative, qualitative and mixed methods (Fellows and Liu, 2015; Saunders et al., 2019). Quantitative methods examine the relationships among observed variables with numerical measures and statistical techniques (Walsh, 2015). Denzen and Lincoln (2018) explained the qualitative method as a method that examines relationships between items to establish meanings using words, images and non-numerical measures. Alternatively, the mixed methods integrate both the quantitative and qualitative methods in a research study (Creswell and Plano Clark, 2011; Teddlie and Tashakkori, 2011). It is worth noting that there are various ways of applying these methods. For quantitative or qualitative methods, when one data collection technique is solely used, it is a ‘mono-method’, but if two or more data collection techniques are used, it is a ‘multi-method’ (Bryman, 2006). With mixed methods, different data collection techniques are employed in a research at a single phase or at different phases sequentially.

Since this study involves multiple phases, with different data collection techniques, the mixed methods offer a dynamic approach that is both interactive and iterative. As it is often associated with pragmatist views, the mixed methods allow quantitative and qualitative data to be ‘merged’ such that the quantitative data can be *‘qualitized’* and qualitative data can be *‘quantisized’* towards problem solving (Saunders et al., 2019).

2.2.4 Research strategies

Research strategy forms the methodological connection between research philosophy and the choice of method to collect and analyse data (Denzin and Lincoln, 2018). In that regard, several research strategies have been developed in literature. The experimental research answers questions in explanatory and exploratory research due to its ability to explain relationship among variables, usually in laboratory or controlled environments (Saunders et al., 2019). The survey frequently answers questions of ‘what’, ‘where’, ‘who’, ‘how much’ and ‘how many’. It is used for exploratory and descriptive research as it produces numerical results for inferential and statistical analysis about beliefs, views, behaviour and expectations (Neuman, 2006). Using the data collected from the survey, possible reasons for particular relationships among variables can be suggested to produce models. Survey strategies using questionnaires are popular and can be used to reach a wide range of participants, although, other techniques (e.g. interviews) can be used (Fellows and Liu, 2015).

While archival research focuses on documentary data in the form of government publications, media documents, minutes of meetings etc., the case study strategy provides deep engagement into a topic from the perspective of an organization or person (Lee, 2012; Yin, 2018). For ethnography, Oates (2006) indicated that it is used to explore the social world or culture of a group in their natural context. Action research is seen as a reflective process in which the researcher works with the team or organization to be studied to improve the situation (Greenwood and Lewin, 2007). In action research, the researcher must consider the accommodating context before embarking on the research study. According to Walsh (2015), grounded theory focuses on generating theories about action or process based on a set of data. It is a reflective process that is used to pursue theoretical enquiry rather than achieving population representativeness.

Among the aforementioned research strategies, the survey strategy provides a more suitable strategy for this study since it has a wider reach and enables the testing of multiple relationships in a single survey (Neuman, 2006). Further, it aids in achieving a representative sample in a cost-saving manner (Fellows and Liu, 2015).

2.2.5 Time horizons

Time horizons are essential components to consider in every research process. The time horizons refer to the cross-sectional and longitudinal dimensions. The cross-sectional dimension provides a ‘snapshot’ of the phenomenon at a particular point in time and the longitudinal dimension observes the phenomena at a certain duration of time to identify trends and changes (Saunders et al., 2019; Fellows and Liu, 2015). The cross-sectional dimension, which usually employs the survey, was adopted in this research due to time constraints in the study.

The data collection methods and the data analysis methods that correspond to the research strategy and adopted in this study are discussed in detail in the subsequent sections.

2.3 RESEARCH METHODS ADOPTED FOR THIS STUDY

The selection of a particular research method mainly depends on the research situation, research objectives and the research questions. Hence, selecting the best research method is not generic but rather contextual (Yin, 1994; Saunders et al., 2012). Further, Akadiri (2011) indicated that the selection of suitable research methods for a study is mainly linked to the kind of data required for the study and the intent of the research objectives. Though the selection of research methods hinges on the contextual research situation, it is widely acceptable that adopting well-known methods ensure meaningful results can be reproduced, and thereby, facilitating comparison with other studies with similar methodologies (ALwaer and Clements-Croome, 2010). Table 2.1 presents for each research objective, the corresponding research methods that were used to achieve it. The research methods were divided in two parts; data collection (literature review, questionnaire survey and expert interviews) and data analysis (mean analysis, factor analysis, FSE, AHP and NFS and content analysis).

Table 2.1 Research objectives and the corresponding research methods

		Research Methods								
		Data Collection				Data Analysis				
No	**Research Objectives**	Comprehensive Literature Review	Questionnaire Survey	Expert Survey	Mean Score + Normalization Analysis	Factor Analysis	FSE	AHP	NFS	Content analysis
1	To identify the important EPSs benefit drivers and to examine the influences of the benefit drivers in EPSs adoption process in Ghana	✓	✓		✓	✓	✓			
2	To identify quantifiable EPSs benefit drivers for evaluation in Ghana.			✓				✓		
3	To identify the critical barriers to EPSs implementation in CP and model their influential relationship patterns on EPSs uptake in Ghana.	✓	✓		✓	✓			✓	
4	To determine the important strategies for EPSs implementation and evaluate their synergistic influences in the promotion of EPSs implementation in Ghana.	✓	✓		✓	✓			✓	
5	To develop an implementation model based on the results of this study, to aid in the promotion and implementation of EPSs in the construction industry in Ghana.			✓						✓
	Remarks	Establish theoretical foundation for research	Two surveys: general survey and expert survey	To validate research outcomes from the study	Appropriate for evaluating significance of factors (Cheng and Li, 2002)	For data reduction of variables and suitable as a precursor for modelling (DiStefano et al., 2009)	Appropriate for vague or fuzzy concepts expressed in linguistic terms (Boussabaine , 2014)	An effective method for determining priority weights and compatibility among items (Wong and Li, 2008)	Ability to determine underlying complex relationships and superior prediction under uncertainties (Jin, 2011)	Appropriate for developing and validating research outputs (Saunders et al., 2012)

Note: FSE – Fuzzy synthetic evaluation; AHP – Analytic hierarchy process; NFS – Neuro-fuzzy systems.
Other statistical analysis including Kruskal-Wallis ANOVA test, Kendall's coefficient of concordance, and sensitivity analysis were conducted.

2.4 DATA COLLECTION METHODS

In choosing research methods, Fellows and Liu (2015) emphasize the need for considering the intended scope and depth of the research. According to Saunders et al. (2012), questionnaire survey is considered to have a broader reach while case study is considered as a narrow investigation and interviews spans between case study and questionnaire survey regarding the breadth and depth. A literature review also provides a thorough and deep insight into existing knowledge and current practices, which helps in identifying knowledge gaps that are relevant. Due to the broad industrial scope and the wider examination of EPSs implementation issues in this study, the literature review, questionnaire survey and interviews were deemed appropriate for this study. The questionnaire survey has the intention to collect data quantitatively while the interview focuses on collecting qualitative data. The combination of these two methods in a study is known as “mixed methods” or ‘mixed-triangulation” research approach (Creswell, 2014). The mixed-triangulation research approach has been identified as an effective research approach that adds value to research outputs by increasing the validity of findings and gaining deeper understanding of phenomena (Creswell, 2014; McKim, 2017). Also, the increase in flexibility helps researchers to either qualitatively or quantitively test outcomes. The mixed-triangulation method was adopted for this study to ensure improved validity, reliability and consolidation of research findings.

2.4.1 Comprehensive literature review

Literature review presents the opportunity to consolidate previous research findings and form a good foundation for developing and advancing knowledge in a research area (Webster and Watson, 2002; Grant, 2009). Also, the consolidated findings from previous studies help in identifying relevant issues pertaining to the research area (Koebel et al., 2015; Rodrigues and Mendes, 2018). This study began with a comprehensive review of relevant materials in literature, that is, academic journal publications, conference papers, refereed publications, textbooks, doctoral theses, internet information and research reports to capture important information on the research area. In addition to academic literature, this research also reviewed reports and publications by relevant organizations, such as the World Bank, European Union (EU), Organisation for Economic Co-operation and Development (OECD) and procurement agencies. This is because, these institutions are primary advocates for transformations in various local construction industries. Additionally, the World Bank, EU and the OECD are reputable international institutions focused on the agenda of development both at the national and global levels. The literature review enabled the capturing of relevant background knowledge about EPSs and the inherent influential factors associated with its adoption. Hence, a good research foundation is presented for the achievement of the study's objectives.

The literature review was conducted in this study to: (i) develop a comprehensive research framework for understanding the main issues of this research; (ii) examine the role and impact of CP within the construction industry; (iii) understand the evolution and experiences of EPSs globally and in Ghana; (iv) identify the potential drivers/benefits for implementing EPSs; (v) identify the potential barriers to the adoption of EPSs; (vi) identify the relevant strategies promoting EPSs uptake; (vii) identify appropriate research methodologies for this study; and (viii) develop the questionnaire for the collection of data.

The literature review is structured into three parts. Part one (Chapter 3) provides an understanding of the nature of procurement in the construction industry, and reviews the concept and implementation characteristics of EPSs in the construction industry. Part two (Chapter 4) reviews the drivers/benefits for EPSs adoption and presents insights into the major benefits and the potential of quantifying these benefits for realization measurements. Part three (Chapter 5) reviews the barriers affecting the use of EPSs and the strategies promoting EPSs implementation on projects. Altogether, these issues provide a solid foundation for the development of an implementation model for promoting the widespread use EPSs in the GCI.

2.4.2 Questionnaire Survey

The survey method is an effective method that is used to acquire data based on a given sample (Saunders et al., 2012; Bryman, 2016). Questionnaire survey provides an economical and efficient way to collect data from a large group of people from different geographical locations (Bell et al., 2018). Further, questionnaire surveys have the advantage of gauging experts' views and experiences while offering quantifiability (Jin and Gambatese, 2020; Yevu et al. 2021d). This study employed the questionnaire survey, as previously indicated, as the primary tool for data collection to provide quantitative assessment of the experiences of the representative sample from the entire study population (Creswell, 2014). Although, questionnaire survey has some shortcomings, such as low response rate, long response periods and risk of bias, it still offers a more effective approach for researchers to investigate myriad factors if procedures are established to ensure a representative sample (Yevu et al., 2021a; Hallowell and Gambetese, 2010). A quantitative questionnaire survey was developed based on the factors derived from the literature review to elicit the experiences of practitioners with EPSs implementation process in Ghana. This helped in consolidating the views of multiple stakeholders across the value chain in the GCI for the identification of critical benefits, barriers and strategies encouraging EPSs uptake in the GCI. This study conducted two kinds of surveys, that is, a general survey and an expert survey using the AHP method.

2.4.2.1 ***Questionnaire development***

2.4.2.1.1 Questionnaire structure

The general survey which comprised of the main questionnaire survey (as shown in Appendix A) was used to explore the experiences and perspectives of practitioners in the GCI. In addition, the AHP questionnaire survey was used to investigate expert's knowledge on EPSs benefits quantifiability.

The main questionnaire survey was organized into three sections. *Section A* – explored the background information of the respondents regarding type of organization, professional training, industrial experience and EPSs experience. *Section B* – dealt with general statements about the adoption of EPS on projects. The respondents were asked to express their levels of agreement or disagreement with the general statements for EPSs adoption using a 5-point rating scale. *Section C* – covered the experiences and perspectives of respondents on the benefit drivers, barriers and promotion strategies concerning EPSs implementation on projects. This section involved three questions. Question 1 asked respondents to indicate their level of agreement or disagreement with the factors listed as main benefit drivers motivating the adoption of EPSs. Question 2 requested respondents to rate how critical the listed barriers are to the implementation process of EPSs. Question 3 required respondents to indicate the importance of various strategies in promoting EPSs use on projects. All the questions required respondents to express their views and experiences using a 5-point Likert scale. Generally, options were created for Questions 1, 2 and 3 to allow respondents insert issues or factors which may have been omitted. This ensures that all relevant issues or factors are captured in the questionnaire.

2.4.2.1.2 *Rating Scales*

Previous studies in construction management research have used different types of scales for rating or ranking items. Rating scales such as a 5-point, 7-point and 9-point rating scales have been used to assess respondent's opinions or experiences on various issues in research (Huo et al., 2019; Ameyaw and Chan, 2015). Among the rating scales used in previous literature, the 5-point Likert scale has been widely accepted and adopted in many similar previous studies (Fox and Skitmore, 2007; Ozorhon et al., 2016). Despite its popularity in previous studies, there were other attributes that contributed to the 5-point Likert scale selection. The 5-point Likert scale presents a more practical approach to solicit for opinions and makes presentation of items easy for respondents' clarification when compared to the complicated scales of 7 and 9 (Ekanayake and Ofori, 2004). Again, the provision of perspectives on a 5-point scale is adequate and effective to facilitate valid statistical analysis and inference (Pallant, 2011; Razkenari et al., 2020). Hence, the 5-point Likert scale was adopted in this study to assess the factors or items in the questionnaire. Considering the Ghanaian context, where the 5-point scale is also popular within previous construction management literature, the use of the 5-point Likert scale improves clarity for respondents understanding. Table 2.2 shows the 5-point Likert scales used in the main questionnaire survey.

Table 2.2 Rating scales for factors in the questionnaire survey

Rating scores definition				
Rating score	Linguistic expression[1]	Linguistic expression[2]	Linguistic expression[3]	Linguistic expression[4]
1	Very low	Strongly disagree	Not critical	Not important
2	Low	Disagree	Less critical	Less important
3	Moderate	Neutral	Neutral	Neutral
4	High	Agree	Critical	Important
5	Very high	Strongly agree	Very critical	Very important

Note: [1,2]Likert scale for the two components in Section B of questionnaire.
[2,3,4]Likert scale for the three components of Section C in questionnaire, respectively.

2.4.2.1.3 *Pilot Study*

The initial questionnaire developed for this research was initially tested in a pilot study. Hazzi and Maldaon (2015) emphasized the need for pre-testing a survey questionnaire to examine the feasibility and design of the questionnaire. In this study, the pilot study assessed the feasibility, clarity and relevance of the questionnaire before conducting the large-scale survey in the GCI. The questionnaire for the preliminary testing was sent to 10 EPSs experts in the construction industry. The selection of the experts was mainly based on their knowledge and experience in the research area (Zhang et al., 2020; Liao and Teo, 2018). The experts were tasked to examine the questionnaire for comprehensiveness and clarity with regard to question formulation, use of technical terms, design, level of complexity and relevance of listed factors (Correia et al., 2021; Oyedele, 2010). Due to the issues of experts' availability and the willingness to respond on time, four responses were returned. These responses were considered adequate for examining comprehensiveness, coherence, relevance and clarity of the questionnaire. The four experts include one professor and three experts. Two out of the three experts were selected from Ghana to ensure the questionnaire was suitable for the Ghanaian context.

The questionnaire was revised based on the responses from the pilot study to obtain a more constructive questionnaire for the general survey. For instance, the responses from the experts suggested reducing the length of the questionnaire by consolidating the strategies with similar focus for promoting EPSs. Therefore, some strategies such as "lower and subsidised cost of EPSs" were eliminated since "availability of financial support schemes for EPSs investment" could effectively address the issue of financial support for EPSs. The final questionnaire was achieved through an iterative process addressing the experts' valuable feedbacks on the initial questionnaire.

2.4.2.1.4 *Sampling techniques for the general survey*

Sampling is an essential technique in research as it is mostly impracticable to have complete responses from the entire population (Saunders et al., 2012; Bell et al., 2018). Also, sampling affords researchers under budget and time constraints to achieve research purposes (Babbie, 2007, Fowler, 2013; Creswell, 2014). This study focused on procurement practitioners in Ghana who are involved in the use of EPSs from the major stakeholder organizations in the GCI (i.e. procurement agencies, client/consulting firms and contractors/developers). These major stakeholders (the target population) play key roles in the implementation process of EPSs on projects due to their job duties and should be able to describe their experiences and perspectives from the Ghanaian context (Ahadzie, 2007; Yevu et al., 2021a). Due to the infantile nature of EPSs development in Ghana, and the unavailability of specific databases through which experts can be selected, using the random probability sampling technique was infeasible and impractical. Specifically, readily available information about the sample frame for this study is scanty. In such circumstances, the non-probability sampling provides alternative techniques to best achieve a representative sample for a study (Saunders et al., 2012). With non-probability sampling, respondents are selected based on the suitability of their experience and knowledge for the particular study, instead of randomly selecting from the population (Patton, 2002; Etikan et al., 2016). To address the difficulties of identifying experts, two main non-probability sampling techniques, that is, the purposive sampling and snowball sampling techniques were adopted in the study.

In using the purposive sampling technique, information-rich practitioners were targeted via the following criteria recommended by Hallowell and Gambetese (2010); (i) practitioners involved in at least one EPSs project, (ii) experts with extensive working experience in the construction industry with good grips on EPSs adoption, and (iii) experts having deep knowledge about

EPSs implementation. Local organizations (private and public) involved with implementing EPSs for construction projects were contacted to identify initial respondents. The initial respondents identified were contacted to assess the expert's suitability for the survey regarding the above-mentioned criteria, and for subsequent recommendation of other knowledgeable experts, resulting in a potential list of respondents. With the snowball sampling technique, potential respondents were asked to share and invite other practitioners they deemed qualified to participate in the survey using the above-mentioned criteria (Bryman, 2016). These criteria ensured robustness in the collection of data from the selection process in this study. Combining these two sampling techniques, more than 200 questionnaires were distributed, thus 208 were directly distributed and many participants acknowledged distributing it to other experts. The mixture of these sampling techniques presents difficulty in calculating the exact number of total questionnaires distributed. Finally, a total of 121 questionnaires with valid responses were received after the survey responses were filtered. The sample size was deemed adequate for further statistical analysis as it compares favourably with previous studies on construction technology adoption and studies that employed FSE and NFS (Wibowo and Sundermeie, 2020; Jin, 2011). More importantly, given the nascent nature of EPSs development in Ghana the sample size attained was deemed suitable.

2.4.2.1.5 *AHP expert survey*

The AHP expert survey was conducted to evaluate and prioritize the quantifiability of critical EPSs benefit drivers derived from the general survey based on expert's assessment/priority weights. The general survey aided in the execution of the AHP survey by first identifying experts with higher experience and qualification from the respondent's background profile (Wong and Li, 2008). Specifically, respondents with more than five years of experience in implementing EPSs on projects were deemed as top experts from the Ghanaian context.

Second, the output of the general survey provided the important benefit drivers and their respective categories needed as inputs for the AHP questionnaire survey.

From the general survey, 29 respondents had more than five years of experience in EPSs and were considered eligible for the AHP survey. Hence, these respondents were invited to evaluate the benefit drivers of EPSs using the AHP questionnaire. Out of 29 invited respondents, 18 experts indicated their willingness and availability for the AHP survey. The AHP questionnaires were distributed to these experts personally and further elaborations were provided on the AHP process to guide the experts in their evaluations, since AHP questionnaires have unique rating scales for pairwise comparison (see Table 2.3). This process is important in achieving the appropriate responses since the use of AHP in the GCI is not widespread. The pairwise comparison using the 9-point AHP rating scale from Saaty (1990) was used to interpret the expert's preferences between benefits. Consequently, 18 completed responses were received and consistency tests were carried out. Since AHP is a judgemental method focusing on specific issues, it has strong abilities of achieving statistically robust results with small sample sizes ranging from 4 to 22 (e.g. Pan et al., 2012; Wakchaure et al., 2009).

Table 2.3 AHP pairwise comparison rating scale

Weight	Definition	Explanation
1	Equal importance	Two EPSs benefits contribute equally to the objective
3 (or 1/3)	Moderate importance	Experience and judgement slightly support one EPS benefit more than the other
5 (or 1/5)	Strong importance	Experience and judgement are very strong in favour of one EPSs benefit over the other
7 (or 1/7)	Very strong importance	One EPSs benefit is favoured strongly, dominant and demonstrated in practice over another.

9 (or 1/9)	Absolute/extreme importance	The evidence favouring one EPSs benefit over the other is the highest possible order of affirmation.
2,4,6,8	Can be used to express intermediate values between two adjacent judgements	When compromise is needed
Reciprocals of previous values	If item "i" has one of the previously mentioned numbers assigned to it when compared to item "j", then "j" has the reciprocal value when compared to "i".	

2.5 DATA ANALYSIS METHODS

The data collected from the surveys were analyzed using various statistical analytical techniques as described in the following subsections.

2.5.1 Reliability and normality tests

The Cronbach's alpha method provides as effective means of examining the reliability of scale items in a survey instrument. The Cronbach's alpha method was used in this study to assess the internal consistency and reliability of items in the survey instrument (Field, 2013; Cronbach, 1951). The Cronbach's alpha coefficient (α) has a value ranging from 0 to 1, with George and Mallery (2003) recommending that α values not less than 0.70 indicate reliable items in the survey instrument. In this study, Cronbach's alpha coefficient (α) value was used to examine whether the collected data on benefit drivers, barriers and the promotion strategies in the survey instrument were reliable for the study. This method has been extensively used in construction engineering management research (Darko et al., 2018). Using SPSS, the value of α is calculated as follows (Li, 2003):

$$\alpha = \frac{k\overline{cov}\sqrt{var}}{1+(k-1)\overline{cov}\sqrt{var}} \qquad (2.1)$$

where k = the number of scale items; $\overline{var}$ = the average variance of the scale items; and $\overline{cov}$ = the average covariance between the scale items. However, the formula can be simplified when the factors are standardized and have common variance, as shown expressed below:

$$\alpha = \frac{k\bar{r}}{1 + (k-1)\bar{r}} \tag{2.2}$$

where $\bar{r}$ = the average correlation among the scale items.

Further, the Shapiro-Wilk test (SW) which is widely adopted for normal data distribution assessment, was carried out for data normality checks. The SW for all factors showed *p-values* <0.05, suggesting that the dataset is not normally distributed (Royston, 1992). In using SW test, the null hypothesis was that "the data was normally distributed" if the alpha value *(p-value*) was above 0.05. However, when the *p-value* from the SW test was below 0.05, the null hypothesis was rejected, indicating that the data was not normally distributed. In this study, all *p-values* of the items in the data from the SW test were below 0.05, hence the data were not normally distributed.

2.5.2 Mean Score Ranking Technique

The mean score ranking technique has been widely used in construction engineering and management research to investigate the relative importance of variables/factors in construction technology processes (Tas et al., 2013; Ameyaw et al., 2017; Huo et al., 2019). Similarly, in this study, the mean score technique was used to determine the relative significance/criticality of variables pertaining to the benefit drivers, barriers and strategies of EPSs implementation. Based on the mean values (MV), the normalization analysis was computed to determine the critical variables (i.e. normalized values ≥ 0.50) and where two or more variables have the same mean values, the higher rank was assigned to the variable with lower standard deviation (SD) (Yevu et al., 2021a; Chan and Adabre, 2019). The MV are calculated using the following formula.

$$MV_i = \frac{\sum_{k=1}^{n} a_{ik}}{n} \tag{2.3}$$

where MV_i = mean value of ith variable; n = total number of respondents; significance rating of variable i by respondent k.

2.5.3 Kendall's Coefficient of Concordance

The degree of agreement between the ratings of the expert respondents was measured using the Kendall's Coefficient of Concordance *(W)* (Kendall and Gibbon, 1990). Kendall's *W* was used to determine whether there was any consensus among the within-group expert ratings and the relative strength of the consensus (Schmidt, 1997). The widespread application of Kendall's *W* in construction related research (e.g. Zhang et al., 2015; Qin et al., 2016; Huo et al., 2019) can be attributed to its simplicity of application and interpretation, with a range from 0 to 1, whereas a value of 0 indicates no consensus and a value of 1 indicates complete consensus or concordance. With Kendall's *W*, the null hypothesis indicates that no agreement exists among respondents' rankings in a particular group, and that the null hypothesis must be rejected when the significance value (*p-value* ≤ 0.001). Kendall's *W* can be calculated using the formula:

$$W = 12 \sum \frac{R_i^2 - 3k^2 N(N+1)^2}{k^2\, N(N^2-1) - k \sum T_j} \tag{2.4}$$

where $\sum R_i^2$ = the summation of the squared sum of ranks for the individual ranked N variables; k = the total number of respondents or rankings; and T_j = the factor for correction needed for the jth set of ranks for the tied ranks, defined as $T_j = \sum_{i=1}^{gj}(t_i^3 - t_i)$, where gj = the number of groups of ties in the jth set of ranks; and t_i = the number of tied ranks in the ith grouping of ties.

2.5.4 Kruskal-Wallis test

The Kruskal-Wallis one-way ANOVA test was adopted in this research to determine if there were any statistically significant differences between the groups of respondents with respect to their rating of the benefit drivers, barriers and strategies concerning EPSs (Wong and Li, 2008). As a non-parametric method, the Kruskal-Wallis test is not based on any stringent requirement or any underlying assumption of population distribution for inter comparisons of three groups or above (Field, 2013). For this study, the Kruskal-Wallis test was performed for inter-group comparisons of three groups of respondents (i.e. regulatory agencies, consultants and contractors).

2.5.5 Factor Analysis

Factor Analysis is a frequent statistical tool with the main purpose of analysing many inter-related and correlated factors among a given set of factors and to reduce the set number by examining the underlying structural dimensions (Pallant, 2011; Thompson, 2004; Fernandes, 2006). It is a well-known multivariate statistical technique for investigating the structural interrelationships and clusters of a large group of variables (Field, 2013; Kline, 2014). To this end, Lingard and Rowlinson, (2006) ascribed the popularity of factor analysis in construction research to its easy interpretation and data reduction. For data reduction using factor analysis, the principal component factor analysis (PCFA) is a more suitable choice (Li et al., 2015a; Fabrigar et al., 1999). In this study, the PCFA was employed to reveal the underlying clusters of benefits, barriers and strategies related to EPSs implementation process. The underlying components generated from the PCFA served as inputs for further advanced analytical applications. There are four steps in conducting factor analysis (Chan et al, 2004):

1. Establish the relevant factors (e.g. benefits drivers) related to EPSs adoption.
2. Compute the correlational matrix for the factors.
3. Extract and rotate each factor.
4. Interpret and name the principal factors as underlying constructs or clusters.

Prior to conducting factor analysis, preliminary tests such as Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity were conducted to check the appropriateness of the data for factor rotation (Fox and Skitmore, 2007). The KMO test was used to measure sampling adequacy and its values ranges from 0 to 1, wherein values above 0.5 (acceptable threshold) suggest the relative compactness of correlation patterns, and thus the FA would produce distinct and reliable factors (Norusis, 2008; Field, 2013). The KMO measure of sampling adequacy represents the ratio of the squared correlations between the variables to the squared partial correlations between the variables (Fellows and Liu, 2015; Field, 2013). The Bartlett's test was used to determine whether the population correlation matrix is an identity matrix or not (Pallant, 2011; Hair et al., 1998). In Bartlett's test, a significant value *(p-value)* <0.05 indicates that the population correlation matrix is not an identify matrix, hence factor analysis is appropriate (Norusis, 2008).

2.5.5.1 Factor extraction and rotation

To conduct factor analysis, two key processes were involved: factor extraction and factor rotation (Fellows and Liu, 2015; Norusis, 2008). Factor extraction was adopted to establish the variables through principal component analysis (factor-solutions) by combining factors.

Principal component analysis was employed due to its effective dimensionality reduction and elimination of redundant information for identification of significant modelling inputs (Li et al., 2015a). Additionally, factor rotation was conducted to achieve a simple structure that was easily interpretable using varimax rotation method since it does well in recovering the model and yielding more accurate estimates (Gerbing and Hamilton, 1996). The factor-solution is usually explained by the amount of variance in the data. The eigenvalue is the sum of the squared factor loadings of the factors and depicts the amount of variance explained by a factor (Cheung et al., 2000). As recommended in previous studies (Kim and Mueller, 1994; Field, 2013), factors with eigenvalues above 1 were considered significant and retained in this study for further analysis. Thus, grouping components with eigenvalues not less than one and variables with factor loadings not less than 0.50, should be retained due to their significant contribution in interpretating a given phenomenon/problem (Matsunaga, 2010). This ensures that groupings derived are significant and adequately represent the problem for further modelling purposes (Li et al., 2015a).

2.6 FUZZY SYNTHETIC EVALUATION METHOD

Fuzzy mathematics describes modern mathematics that are used to handle complex and ill-defined fuzzy phenomena, considering the fact that real world problems are characterised by vague and incomplete data (Fayek, 2020). The theoretical basis of fuzzy synthetic evaluation (FSE) is the fuzzy set theory, introduced by Zadeh (1965). A fuzzy set denotes a set with varying degree of membership, ranging from a closed interval between 0 and 1 (Zadeh, 1965). The degree to which each element belongs to the set is represented by the membership function values. Thus, the lesser or greater an element belongs to a fuzzy set is indicated by a smaller or larger membership value respectively (Xu et al., 2010). FSE has been enriched continuously since its introduction and has been increasingly applied to solve practical issues in project environments (Xu et al., 2010). Based on fuzzy mathematics, FSE has the ability to use linguistic variables to determine fuzziness which is inherent in human cognitive process. These linguistic variables are not numbers but expressive words in natural language such as high, moderate and low, which typically describes the fuzzy concept (Yevu et al., 2021a). The FSE method helps in the modelling of multi-attributes towards the development of an overall output (Xu et al, 2010). In effect, FSE method provides a suitable technique for modelling decision-making environments and analysing complex systems when the pattern of indeterminacy is subjective, imprecise, incomplete and vague (Zadeh, 1994; Boussabaine, 2014).

The FSE has the capability of classifying samples at a defined centre of classification (Lu et al., 1999). Also, this technique is employed to assess multi-criteria and multi-attributable decision-making, which are usually conflicting and uncertain in nature (Sadiq and Rodriguez, 2004). For instance, the fuzziness associated with expert's decisions expressed in linguistic terms could be resolved using FSE technique to achieve practical decisions (Boussabaine, 2014). Further, the fuzzy technique has the advantage of incorporating experts' knowledge and working with small sample sizes. The fuzzy technique has been applied to tackle many construction engineering problems in research including determinant factors modelling and risk evaluation (Ameyaw, 2015; Liu et al., 2013). In this study, the FSE technique was used to evaluate and develop a model for the influential benefit drivers of EPSs implementation in construction projects.

2.6.1 FSE Procedure

The procedure for the fuzzy technique modelling is described in the following steps (Xu et al., 2010; Ameyaw and Chan, 2015):

1. Establish a set of basic criteria (or factors) $U = \{u_1, u_2, u_3, \ldots, u_n\}$ where n is the number of factors.
2. Establish a set of grade alternatives presented in linguistic terms for the factors, $H= \{h_1, h_2, h_3, \ldots, h_n\}$ where $(h_1 \ldots h_n)$ is the grade alternative. The grade alternative is the measurement scale. Hence, the 5-point Likert scale used to assess the factors is the grade alternatives, e.g. h_1 = not important, h_2 = least important, h_3 = neutral, h_4 = important and h_5 = very important.
3. Determine the weightings for each factor or component, by computing the weight using the following equation:

$$W_i = \frac{M_i}{\sum_{i=1}^{5} M_i} \quad , 0 \leq W_i \leq 1, \quad \sum W_i = 1 \qquad 2.5$$

where W_i is the weighting, M_i is the mean score of a specific factor or component, and $\sum W_i$ is the summation of the mean scores.

4. Determine a fuzzy evaluation matrix $R = (r_{ij})_{mxn}$, where r_{ij} represents the extent to which alternative h_j satisfies the basic criterion (factor) u_j in a fuzzy environment. The fuzzy function matrix R is defined as:

$$R = \begin{vmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{vmatrix} \qquad 2.6$$

5. Determine the final fuzzy evaluation by considering the weightings (step 3) and fuzzy evaluation matrix (step 4) through the following equation:

$$D = W_i \bullet R \qquad 2.7$$

where D represents final evaluation matrix; W_i is the weighting vector; R is the fuzzy evaluation matrix; and $\bullet$ represents the fuzzy composition operator.

2.7 NEURO-FUZZY SYSTEMS (NFS)

With practical construction management problems characterized by high levels of complexity, human judgements and dynamic interactions due to uncertain project environments, artificial intelligence (AI) techniques are increasingly being applied to solve these real-world problems (Tiruneh et al., 2020). The application of AI has gained attention in recent times due to its ability to effectively address complex issues under uncertainties as evidenced in previous studies (Gerek, 2014; Akinade and Oyedele, 2019). AI techniques include fuzzy systems, artificial neural networks (ANN), support vector machines and expert systems. However, hybrid systems, thus combining two or more AI techniques – such as neuro-fuzzy systems – are becoming prominent due to their ability to address the weakness and combine the strengths of stand-alone AI techniques (Akinade and Oyedele, 2019). Among the hybrid systems, the neuro-fuzzy systems are dominant because of their ability to attain interoperability and accuracy (Lin, 1996). This study adopted the most widely used neuro-fuzzy system called adaptive neuro-fuzzy inference system (ANFIS), introduced by Jang (1993). The ANFIS has an effective learning and reasoning capabilities since it integrates strengths of ANN and fuzzy systems while addressing the limitations of the stand-alone techniques. For instance, fuzzy systems are strong in reasoning inference and knowledge representation but weak in learning capabilities while ANNs have great learning capabilities and weak reasoning inference (Akinade and Oyedele, 2019). To this end, ANFIS which integrates ANN and fuzzy systems, provides a robust, fast and more predictive capabilities to solve complex problems that are uncertain, dynamic and nonlinear.

The application of ANFIS for construction related problems include waste prediction, supplier evaluation and prediction, selection of project managers, risk allocation and cost prediction (Akinade and Oyedele, 2019; Tavana et al., 2016; Rashidi et al., 2011; Jin, 2011; Gerek, 2014).

Similarly, in this study, the ANFIS technique was adopted to model and predict the influences of the barriers and promotion strategies regarding EPSs implementation. Considering that the influential interrelationships among the factors in the barriers and strategies categories are complex and non-linear, applying neuro-fuzzy technique was suitable for evaluating these influences for EPSs adoption. The groupings of the critical barriers/strategies served as input variables for the NFS. Since experts' judgements on the critical barriers/strategies were based on linguistic expressions that tend to be subjective and uncertain, the neuro-fuzzy technique was adopted. The neuro-fuzzy technique integrates the strengths of fuzzy systems and neural networks, making it capable of handling nonlinear, complex, subjective and uncertainty involved in predicting the influence of barriers/strategies in EPSs implementation within CP (Tiruneh, et al., 2020; Akinade and Oyedele, 2019). Details for developing NFS are discussed as follows.

2.7.1 Development of NFS

The NFS mainly contains two learning elements – structure and parameter learning (Li et al., 2013; Premkumar and Manikandan, 2015), which are combined into an integrated learning process (Jin, 2011) (see Fig. 2.1). The learning process begins with transforming domain knowledge or experience into a rule base for a fuzzy inference system database (Gerek, 2014). The learning process was conducted sequentially using the learning structure element (LSE) and the learning parameters element (LPE) with the dataset obtained in this study. The generation of fuzzy rules and adjustments of parameters enables the NFS to learn and synthesize the benefits of fuzzy logic and neural networks for problem solving (Jin, 2011).

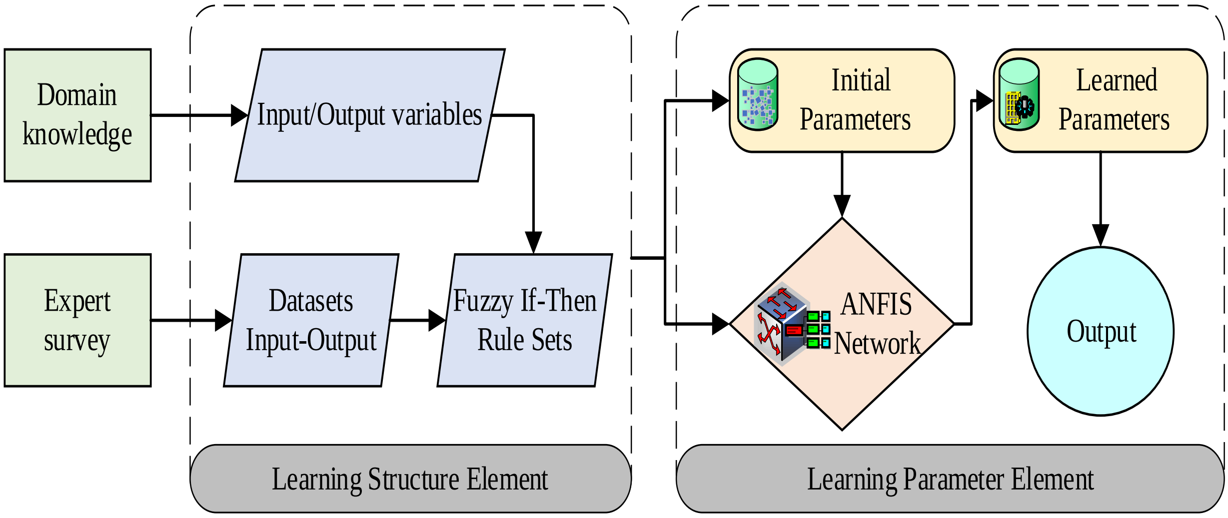

Fig. 2.2 Structure of the NFS

2.7.1.1 Learning structure element

The LSE has the functions of determining the input and output variables and then generating the if-then fuzzy rule sets from the input/output dataset. These fuzzy rules and variables were then employed in determining the LPE structure in the neuro-fuzzy system. Generally, the fuzzy if-then rules are expressed below:

Rule 1: If x is A_1 and y is B_1 then $f_1 = p_1x + q_1y + d_1$,

Rule 2: If x is A_2 and y is B_2 then $f_2 = p_2x + q_2y + d_2$.

where $f(x,y)$ is the first-order polynomial based on the Sugeno fuzzy model, x and y are numerical inputs and f is the output, and A and B are numerical variables, and p, q and d are parameters determining the input-output relationships.

The input and output variables are obtained from the field dataset in this study. The input variables (IVs) for the NFS were derived from the groupings of barriers and strategies. Further, appropriate aggregate mean weights of influences for IV were generated for the neuro-fuzzy model.

All IVs were evaluated by a set of fuzzy values, e.g. low (L) and medium (M) and high (H). Values for input variables were obtained from respondents' evaluation of the observed variables using the rating scale and the aggregate means. Each fuzzy value obtained is a fuzzy set determined by a membership function (MF) (Gerek, 2014). Among the commonly adopted MFs includes trapezoidal functions, gaussian functions and triangular functions. However, this study adopted the Gaussian functions due to its good ability of achieving smoothness and avoiding zero in the denominator of a MF (Jin, 2011). Also, it has been applied in several construction-related studies. The symmetric Gaussian function can be expressed as follows:

$$\mu(x;\, \sigma, c) = e^{\frac{[-(x-c)^2]}{(2\sigma^2)}} \qquad (2.8)$$

where σ is the variance and c is the curve mean. These are the premise parameters that define the width and center of the MFs respectively.

2.7.1.2 Learning Parameter element

With the input and output variables established, the neuro-fuzzy learning structure is developed using the fuzzy rules determined for the LPE. The LPE tunes the MFs by modifying parameters to minimize output error or maximize model performance (Gerek, 2014; Jang, 1993). The LPE was conducted using ANFIS. First introduced by Jang (1993), the ANFIS architecture estimates and embeds the fuzzy reasoning from a fuzzy inference system (FIS) into adaptive networks to facilitate learning from input-output dataset. The FIS entails two rule bases (If-Then) via Sugeno FIS. The ANFIS learning algorithm combines the least squares estimate and gradient-descent optimization methods. Details of the ANFIS architecture and the learning algorithm for LPE are presented in subsequent subsections.

2.7.1.3 Network architecture of ANFIS

The architecture of ANFIS consists of several nodes connected through directional links where each node is defined by a function and nodes within the same layer perform the same type of functions. The proposed neuro-fuzzy system using the ANFIS is the first-order Sugeno-type based on the multilayer neural network. The Sugeno system was adopted because it is more effective and compact with well adapted linear techniques and optimization (Takagi and Sugeno, 1985; Gerek, 2014). In addition to the input and output layers, the architecture has five hidden layers. Nodes within the hidden layers perform based on MFs and fuzzy rules, which makes it advantageous over conventional feedforward neural networks with difficult interpretation of hidden layers (Tavana et al., 2016). The ANFIS architecture is shown in Fig. 2.2 and layers are explained as follows.

Input layer: Input layer nodes represent the crisp input values. The *m*th IV value is represented by x_m, where $m \in \{1, 2, \ldots, 5\}$. In this layer, each node only connects to nodes in the next layer (layer 1) corresponding to the MFs of the fuzzy values representing the IV.

Layer 1: Every node *n* in layer one is a square node (J_n^m) with a MF defining fuzzy values of IVs. The outputs in this layer denote membership values of crisp input values x_m. The Gaussian function was employed as MFs, hence the output is expressed using the formula:

$$O_l^{(1)} = \mu_{J_l}(x) = e^{[-(x_m - c_l^m)^2]/2\sigma_l^{m^2}} \tag{2.9}$$

where O_l^1 is the MF of $\mu_{J_l}(x)$; c_l^m and σ_l^m are premise parameters of the MF representing *k*th fuzzy value of the *m*th IV; (1) represents layer 1; $m \in \{1, 2,\ldots 5\}$; and $l \in \{1, 2, 3\}$(i.e. three fuzzy values).

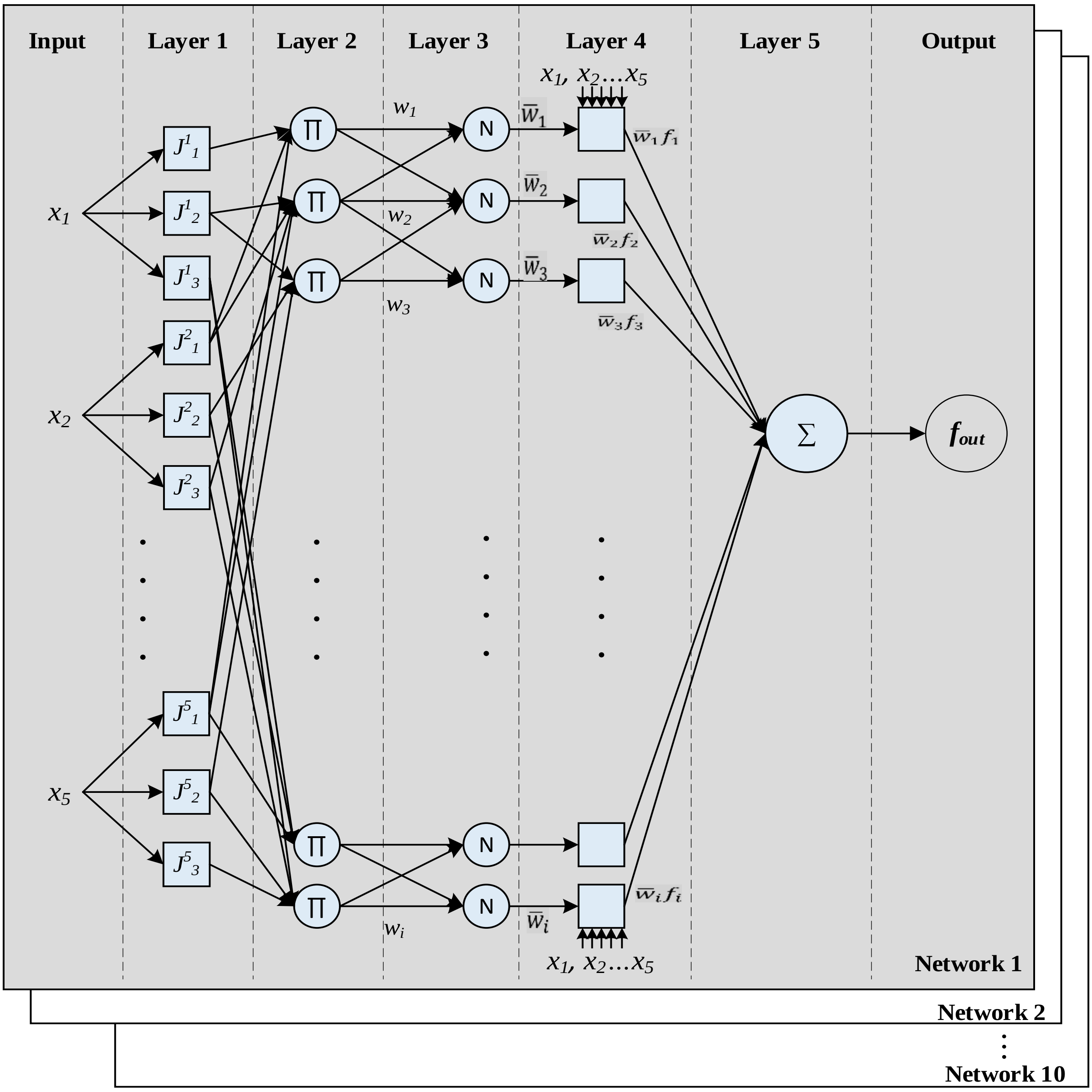

Fig. 2.3 Architecture of ANFIS Network

Layer 2: Every node (п) in this layer is representing the if-part of the fuzzy rule. Circle nodes multiply the incoming signals and the products are transmitted as outputs. This denotes the firing strength (w_i) of the rule.

$$O_i^{(2)} = w_i = \prod_{m=1}^{5} O_l^{(1)} \tag{2.10}$$

where (2) represents layer 2; i is the index of fuzzy rules; and $i \in \{1, 2, \ldots, n\}$, in which n is number of fuzzy rules generated in the LSE.

Layer 3: Every node (N) in this layer computes the ratio of the ith rule's firing strength to the sum of all rules firing strength.

$$O_i^{(3)} = \overline{w}_i = \frac{w_i}{w_1 + w_2 + \cdots + w_n} \tag{2.11}$$

where w_n denotes the last firing strength. Each node's output is called the normalized firing strength.

Layer 4: In layer 4, every node i is adaptive with a node function f_i. The output is given as:

$$O_i^{(4)} = \overline{w}_i f_i = \overline{w}_i (p_i x_1 + q_i x_2 + r_i x_3 + s_i x_4 + t_i x_5 + z_i) \tag{2.12}$$

where $\overline{w}_i$ is the output of layer 3 and $p_i, q_i, r_i, s_i, t_i \; and \; z_i$ are adjusted consequent parameters.

Layer 5: The single node in the last layer computes the overall outputs from layer 4 by using formula:

$$O_i^{(5)} = \sum_i \overline{w}_i f_i = \frac{\sum_i w_i f_i}{\sum_i w_i} \tag{2.13}$$

where $\overline{w}_i$ is normalized firing strength.

Output layer: The output layer only receives the single node from layer 5 and that is the final output of the ANFIS system.

2.7.1.4 Learning algorithms for parameters

The learning process of ANFIS entails adaptation of learning weights and adaptation of non-linear MFs (Jang, 1993). The ANFIS system tunes premise and consequent parameters by adjusting the parameters of MFs using suitable algorithms for parameter learning. Since ANFIS was adopted in LPE, the hybrid learning algorithm which integrates least squares estimator and gradient descent-based back propagation algorithms for optimizing the premise and consequent parameters was applied (Jang, 1993). The propagation of forward pass and backward pass (epoch) is needed for hybrid learning algorithms to mimic the dataset. In construction related research, ANFIS algorithms have been used to solve various problems such as prediction, optimization and modeling in supply chains, real estate and risks (Akinade and Oyedele, 2019; Gerek, 2014; Jin 2011; Tavana et al., 2016; Rashidi, 2011).

2.7.2 Neuro-fuzzy model training

The dataset gathered in this study was used for training and evaluation of the model. The training set was divided into two disjoint datasets, thus training estimation sub-set for enhancing model selection and model testing sub-set for validating the model. The partitioning of the datasets enhances the examination of various models for selection by checking it with a separate validation dataset. Also, this approach guards against overfitting with the validation subset since its performance is tested with the evaluation dataset for generalization (Haykin, 1999). To ensure the learning model remains adaptive and preserves learned knowledge while learning new things, the early-stopping training method was employed to tackle overfitting

(Amari, 1995). For each epoch, the session training was stopped and the model network was tested on the validation dataset. The early-stopping method improves generalization performance of model networks over extensive training.

The multi-fold cross-validation method was used to split the datasets for training in this study. The multi-fold cross-validation uses limited data from the total dataset to estimate the model's expectation or prediction from an untrained dataset (Wong, 2015). Out of 121 datasets in this study, a total of 110 datasets were employed to train the model using 85-15 percent ratio (i.e. 85% for training estimation and 15% for model validation). For each round of training, a different pair of datasets (15%) was left out for model validation and this iteration process was repeated many times. The root-mean-square error (RMSE) for model estimation and validation were used to select the best performing model for the barriers/strategies regarding EPSs implementation (Akinade and Oyedele, 2019).

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{t_{obs,i} - y_{mod,i}}{n}} \tag{2.14}$$

where n = number of datasets; $t_{obs,i}$ = hinderance level observed in the *i*th case; and $y_{mod,i}$ = predicted hinderance level in the *i*th case by the model.

2.7.3 Model performance evaluation and sensitivity analysis

The performance evaluation of the neuro-fuzzy model is based on the evaluation dataset. The evaluation dataset, which is different from the validation dataset, consists of data cases reserved from the total data sample obtained in this study. To evaluate performance, besides RMSE, a set of performance indexes were employed including mean percentage error (MPE) and mean absolute percentage error (MAPE) to measure and validate the prediction of the model developed. While MPE indicates the model's tendency to over-or-under forecast, MAPE measures the magnitude of errors (Jin, 2011). These performance indexes have been used in several studies for model performance (Akinade and Oyedele, 2019; Gerek, 2014; Jin, 2011).

$$MPE = \sum_{i=1}^{n} \frac{t_i - y_i}{t_i} \text{ x } 100\%/n \quad (2.15)$$

$$MAPE = \left| \sum_{i=1}^{n} \frac{t_i - y_i}{t_i} \text{ x } 100\% \right| /n \quad (2.16)$$

where n = 11; t_i *and* y_i denote the observed and model output of the *i*th data case.

The set of IVs values for each evaluation data pair were entered into the trained neuro-fuzzy model, respectively. The predicted hindrance levels by the neuro-fuzzy model were compared with the observed hindrance levels in this study.

Further, sensitivity analysis was conducted to examine the various influence degrees of inputs on the output of a model developed (Ikram, 2020; Patel and Jha, 2015). In this study, to enhance better understanding of the complex dynamics of barriers and strategies, sensitivity analysis was conducted to show the different influence levels arising from various combinations of inputs. In conducting the sensitivity analysis, values of selected inputs were varied while the other inputs were kept at their desire values (El-Gohary et al., 2017). For purposes of examining influence levels from subjective experts' judgements, the barriers/strategies inputs were derived from the MF ranges and assigned values. This approach enables linguistic expressions (assigned values) to adequately represent the uncertain and imprecise experiences within the project environment.

2.8 MULTI-CRITERIA DECISION ANALYSIS: AHP

The AHP technique as introduced by Saaty (1980), is a mathematical decision-making tool in multi-criteria situations. It is a logical and problem-solving framework developed through the structure of experiences and judgements into a hierarchical structure of elements affecting the resulting decisions (Saaty, 2000). The structured approach from AHP allows preferential perspectives to be gathered from the decision makers or experts. AHP is advantageous when decision makers or experts have to make a choice and prioritize elements (Dyer and Forman, 1992) compared to conventional methods for decision analysis. With AHP, the expert's subjective judgements are effectively weighted for the elements in the decision process (Saaty, 1994), and used for generating priority weights for the decision criteria to ensure effectiveness in allocating resources by organizations or project teams. AHP presents a comparative platform for decision elements to be compared against each other towards certain criteria and be ranked with priorities to aid resolve tangible and intangible elements (Saaty, 2000).

The AHP techniques facilitate the structuring of decision complexity into rational decision hierarchy for evaluating tangible and intangible elements with regard to various conflicting objectives (Dyer and Forman, 1992). For instance, in project management, project managers are faced with problems of deciding on competing elements within a decision environment that is uncertain, ill-defined and complex (Al-Harbi, 2001). AHP is well-known for providing effective decision solutions in such circumstances. In using AHP, the experts are able to identify and evaluate the elements relevant for better decision-making. Further, the analytic process of AHP ensures that consistency of the expert's judgement is checked for validity and reliability (Saaty, 1990).

Applications of AHP include critical success factors, risk assessment, plant and equipment selection, pre-qualification assessment of contractors and lifecycle assessment for sustainability (e.g. Cheng and Li, 2002; Zou et al., 2010; Shapira and Goldenberg, 2005). AHP was employed in this study due to its ease of application and ability to infuse expert's knowledge and experience in the decision-making process with relatively small sample sizes. In this study, AHP was adopted to establish prioritized criteria for quantitative assessment of the benefit drivers of EPSs. Since the benefits of EPSs are numerous and interact, AHP provided an objective approach for quantitative assessments of EPSs benefits.

The process for developing an AHP model comprises of six steps (Saaty, 1994):

2.8.1 Step 1: Define the problem and objective

Define the problem and its circumstances and set the decision-making objective. In this study the experts determined the importance of the benefits drivers to EPSs. Clear definition of the problem is critical for expert to make judgments.

2.8.2 Step 2: Formation of hierarchy

A hierarchy structure was developed for the problem after the problem is defined. It is worth noting that the formation of the hierarchical structure is flexible in AHP to allow the structure to be adaptable to the contextual situation. At this stage, the objective of the task was broken down in criteria and sub-criteria. Starting from the main objective of this study at the highest hierarchy, the main criteria and sub-criteria were structured in descending manner for experts' judgements.

2.8.3 Step 3: Pairwise comparison

Upon completing the hierarchy structure, each category on the respective hierarchical structure produces a matrix. For instance, if a category has six decision elements, a 6x6 matrix is produced. With this matrix, experts were expected to complete the AHP questionnaire by comparing the strength and contributions of both elements in the matrix box towards the main objective. This process is called the pairwise comparison. In pairwise comparison, experts' judgement are based on determining which element contributes more when compared to the other element for the decision criteria. Pairwise comparison has the advantage of comparing two elements at the same time, hence expert's judgmental weights are freed from further interacting influences (Cheng and Li, 2002). Typically, a 9-point Likert scale as shown in Table 2.3, was used to present possible answers for the expert's choice, and then these choices were calculated in weighted scores. The presentation of data was produced in a matrix format for pairwise comparison (Saaty, 1980). For example, there are *"p"* elements to be compared, then the total judgments to be made is $p(p-1)/2$. A pairwise comparison of a given matrix *"X"* is derived as follows:

$$X = \begin{bmatrix} m_{11} & m_{12} & m_{13} & \dots & m_{1j} & \dots & m_{1p} \\ m_{21} & m_{22} & m_{23} & \dots & m_{2j} & \dots & m_{2p} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ m_{i1} & m_{i2} & m_{i3} & \dots & m_{ij} & \dots & m_{ip} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ m_{p1} & m_{p2} & m_{p3} & \dots & m_{pj} & \dots & m_{pp} \end{bmatrix} = (m_{ij})_{p \times p} \tag{2.17}$$

where X = pairwise comparison matrix; m_{ij} = relative importance of elements *"i"* when compared to elements *"j"*; and p = number of elements in the set.

Though pairwise comparison is time consuming, it is an effective approach for gathering expert information for decision making while ensuring accuracy (Cheng and Li, 2002). To mitigate this concern, the number of elements listed for comparison in one matrix was reduced and sufficient time was given for experts to answer the AHP questionnaire.

2.8.4 Step 4: Consistency test

With the application of AHP, checking for consistency of the comparative judgments is critical due to the subjectivity in expert's decisions (Doloi, 2008). Hence, a consistency measurement was conducted for each judgment matrix of the expert's respondents respectively, to avoid errors in the AHP assessments (Lin et al., 2008). This ensures that data attained was valid for inclusion in the next stages. For each pairwise comparison matrix, maximum eigenvector and eigenvalue can be calculated by the right eigenvector method (Saaty, 1990). The eigenvector derives the weights of the elements while the consistency measurement of the judgment is given by the maximum eigenvalue. The formula for the right eigenvector is as follows (Saaty, 1990):

$$\lambda_{max} = \sum_{j=1}^{p} \frac{XW}{pw_i} \ (i = 1, 2, 3, \dots, p) \qquad (2.18)$$

where λ_{max} = the largest eigenvalue of matrix *X*; *X* = pairwise comparison matrix; *W* = matrix of weights of decision criteria and elements respectively; w_i = weights of each decision criteria and elements.

If there were no inconsistency in the judgement, λ_{max} should be equal to p. Since experts' responses may not be perfectly consistent, AHP allows for acceptable levels of inconsistency measurement. The consistency ratio (CR) was used to determine the judgement consistency using the formula (Saaty, 1990):

$$\text{CR} = \frac{CI}{RI} = \frac{1}{R1} \left(\frac{\lambda_{max-p}}{p-1}\right) \qquad (2.19)$$

where CR = consistency ratio; *CI* = consistency index; and *RI* = average random consistency index as shown in Table 2.4.

Table 2.4 Average random consistency index

p	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

when CR < 0.1, results from the matrix are satisfactorily consistent, hence it is valid, otherwise it should be considered invalid or inconsistent, and therefore should not be considered for further analysis.

2.8.5 Step 5: Weight determination (w_i)

The AHP scales the weights of the decision elements (EPSs benefit drivers) in each level of hierarchy, with respect to the criteria (quantitative criteria). After data collection for the AHP questionnaire, the data were analysed to determine the weight of each element and criteria as detailed below:

From Eq. 2.17, the product of relative importance is calculated for each element and criteria using the arithmetic (Tam et al., 2007):

$$n_i = \prod_{j=1}^{p} a_{ij} \quad (i = 1, 2, 3, \dots, p) \qquad (2.20)$$

where n_i – product of relative importance of each row of decision criteria and elements; a_{ij} = relative importance of elements decision criterion *"i"* when compared to element criterion *"j"*; and p = number of elements in the set.

Then, from Eq. 2.18, the vector $\overline{w_i}$ is computed using the formula:

$$\overline{w_i} = \sqrt[p]{n_i} \quad (i = 1, 2, 3, \dots, p) \qquad (2.21)$$

where $\overline{w_i}$ = p^{th} power root of n_i.

Next, the weights of decision criteria and elements are determined by normalizing the vector $\overline{w_i}$ with the arithmetic:

$$w_i = \frac{\overline{w_i}}{\sum_{i=1}^{p} \overline{w_i}} \ (i = 1, 2, 3, \ldots, p) \quad (2.22)$$

where w_i = weights of elements and criteria.

2.8.6 Step 6: Final comparison scores computation

The final process of the AHP analysis is to compute the final scores which was used as the basis for selecting the best solution for the problem. When all the weights of the elements under each decision criterion were calculated for the categories, a given matrix of *Y* was formed for the weights of the elements:

$$Y = \begin{bmatrix} w_{11} & w_{12} & w_{13} & \cdots & w_{1j} & \cdots & w_{1n} \\ w_{21} & w_{22} & w_{23} & \cdots & w_{2j} & \cdots & w_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ w_{i1} & w_{i2} & w_{ij} & \cdots & w_{ij} & \cdots & w_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ w_{m1} & w_{m2} & w_{m3} & \cdots & w_{mj} & \cdots & w_{mn} \end{bmatrix} \quad (2.23)$$

where *B* = matrix of weights of element for each decision criterion; *j* = 1, 2, 3, …, *n*; *i* = 1, 2, 3, …, *m*; w_{m1} = weight of element *j* under decision criterion *i*; *m* = number of elements in the set; and *n* = number of decision criteria.

Additionally, for all decision criteria, a matrix of weights, *Z*, is formed:

$$Z = [w_1, w_2, w_3, \ldots, w_i, \ldots\ w_n]T \quad (2.24)$$

where *Z* = matrix of weights of decision criteria; w_1 = weight of each decision criterion. Forming a matrix of all elements, *M*, is derived from the product of the two matrices, *Y* and *Z*:

$$M = Y \times Z \tag{2.25}$$

where M = matrix of element final scores; Y = matrix of weights of elements for each decision criterion; and Z = matrix of decision criterion.

Finally, the best solution to the problem is chosen from the element with the maximum value in M matrix, thus $max(M_1, M_2, M_3, \ldots, M_m)$.

2.9 CONTENT ANALYSIS

Content analysis is defined as a systemic technique for synthesizing research data and outputs into categories based on coding principles and understanding of the research context (Stemler, 2001, Saunders et al., 2012). The use of content analysis is not exclusive to texts, but also includes the examination of figures and any other relevant material (Mayring, 2004). Generally, content analysis can be conducted to yield either qualitative data or quantitative data or both (Fellows and Liu, 2015). Both types of content analysis require the categorization of words (texts), themes and concepts from primary data sources or secondary data sources (e.g. research documents). While qualitative content analysis focuses on understanding and interpreting the meaning of the data, the quantitative content analysis focuses on measuring and counting to yield numerical values from the categorized data for rankings and frequencies (Mayring, 2015; Lock and Seele, 2015). Fellows and Liu (2015) revealed that the way these content analysis techniques are applied depend on the nature of research problem, and the content category synthetization choices depends on the research issues.

Within construction management literature, this technique has been applied in several areas to examine or develop tools, criteria, frameworks and models based on document analysis and a study's outcomes (Zhang and Wildemuth, 2009; Osei-Kyei, 2017). This study adopted content analysis to evaluate extant literature on EPSs and consolidate the research outputs from this study in the development of the implementation model. In evaluating EPSs literature, the qualitative and quantitative content analysis were employed on secondary sources of data (publications). In using the qualitative content analysis, research documents on EPSs were searched to identify themes (i.e. issues) and for subsequent coding and categorization. Each document was search for themes relevant to the specific EPSs problem in this study in a guidebook. These themes were generated through a multiple pass system that confirms, amends or supplements the identified themes. This allowed issues relevant to the specific EPSs problem to be identified and correlations among the identified issues to be highlighted. Further, the quantitative content analysis was used to produce the frequencies of issues over the years. In addition, the aspect of understanding what a data means in qualitative content analysis was employed in the development of the implementation model for validation. The study's findings formed the basis of secondary data upon which '*rational*' patterns of categories were determined and synthesized to develop the implementation model. As recommended by Fellows and Liu (2015) for validation checks of content analysis outcomes, this study conducted a validation exercise to assess the comprehensiveness and reliability of the implementation model.

2.10 BACKGROUND INFORMATION OF RESPONDENTS

The background profiles of the respondents are shown in Table 2.5 and Fig. 2.4, Fig. 2.5 and Fig. 2.6. Table 2.5 shows that the respondents have extensive experience in the construction industry with majority (95%) having more than 5 years industrial experience. Out of 121 respondents, 49 had 1-3 years experience in EPSs, 60 had 4-6 years experience and 12 had 6-8 years experience. Given that EPSs were recently introduced into the Ghanaian construction industry, the high industrial experience coupled with the relatively low EPSs experience was deemed representative and reasonable for this study. Concerning respondents' organizations, 67 respondents were from consultant companies while 28 and 26 were from contractor and regulatory authority companies respectively. In addition, Table 2.5 shows the diversified professions of respondents including project managers (24.8%), engineers (14.1%), quantity surveyors (53.7%), architects (4.1%) and procurement officers (3.3%). From Fig. 2.3, 63.1% of respondents had used EPSs on less than five projects. With the type of EPSs tools used, majority (56.2%) had used e-tendering and e-invoicing tools (Fig. 2.4), mostly (71.1%) at the pre-contract and post-contract stages (Fig. 2.5). From Fig. 2.7, most of the respondents had used the EPSs tools (i.e. e-tendering, e-invoicing, and e-auction) in four to six projects at both the pre-contract and post-contract stages. Therefore, the respondents' profile provided diversified and well experienced professionals to enhance appropriate representation and adequate information on EPSs implementation issues in Ghana.

Table 2.5 Background profile of respondents

Background Profile	Frequency	Percent	Years of experience							
			Construction industry					EPSs		
			1-5	6-10	11-15	16-20	>20	1-3	4-6	6-8
Organizations										
Consultant	67	55.4	1	14	27	17	8	28	38	1
Contractor	28	23.1	0	6	16	6	0	10	14	4
Regulatory Authority	26	21.5	5	9	4	6	2	11	8	7
Subtotal	121	100.0	6	29	47	29	10	49	60	12
% of subtotal			5.0	24.0	38.8	24.0	8.2	40.5	49.6	9.9
Professions										
Project Manager	30	24.8	1	5	6	15	3	4	22	4
Engineer	17	14.1	0	4	9	4	0	11	4	2
Quantity Surveying	65	53.7	3	18	30	7	7	30	29	6
Architect	5	4.1	0	0	2	3	0	0	5	0
Procurement officer	4	3.3	2	2	0	0	0	4	0	0
Subtotal	121	100.0	6	29	47	29	10	49	60	12
% of subtotal			5.0	24.0	38.8	24.0	8.2	40.5	49.6	9.9

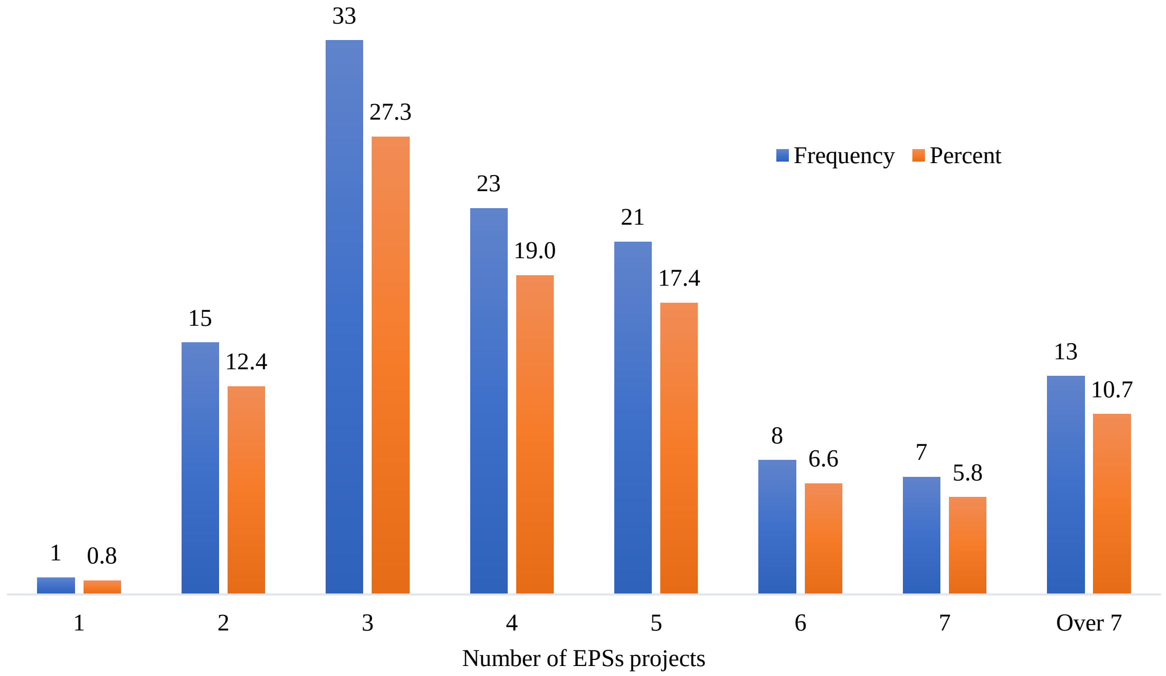

Fig. 2.4 Number of projects that used EPSs

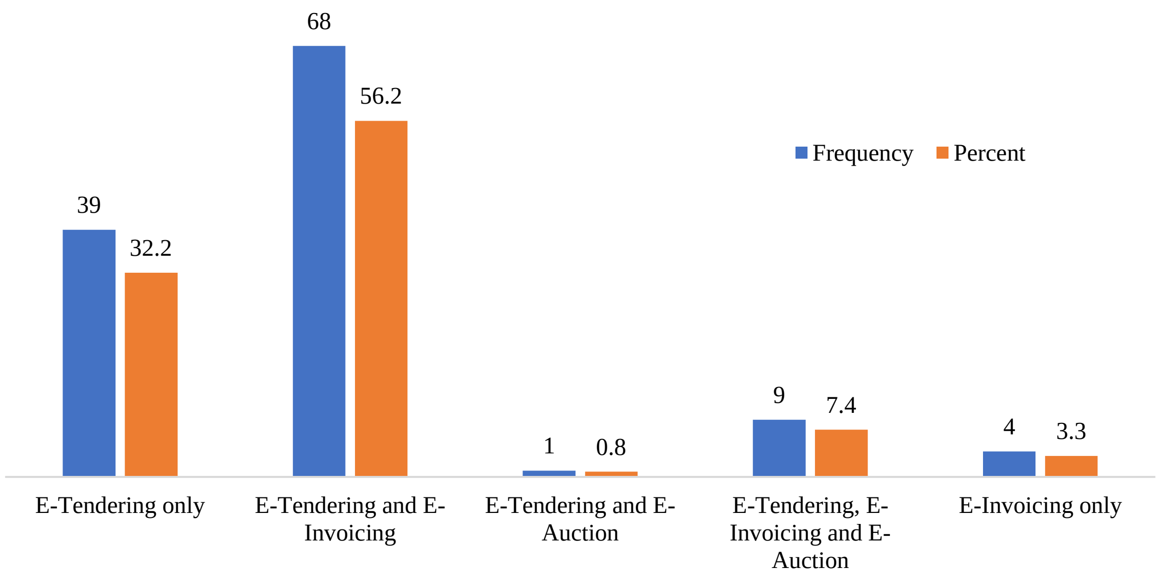

Fig. 2.5 Type(s) of EPSs tool used on projects

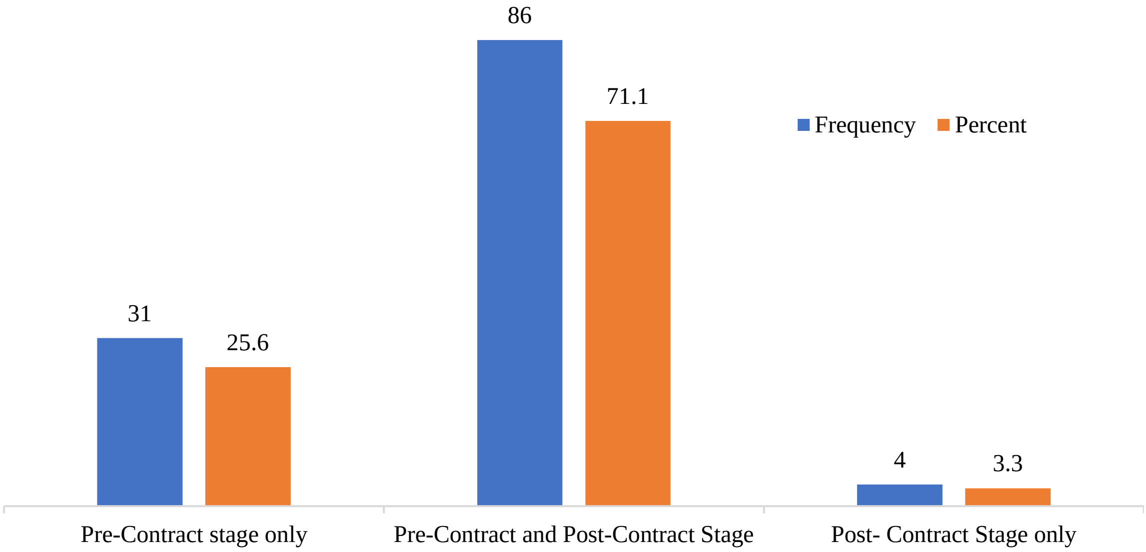

Fig. 2.6 Stage of project for EPSs involvement

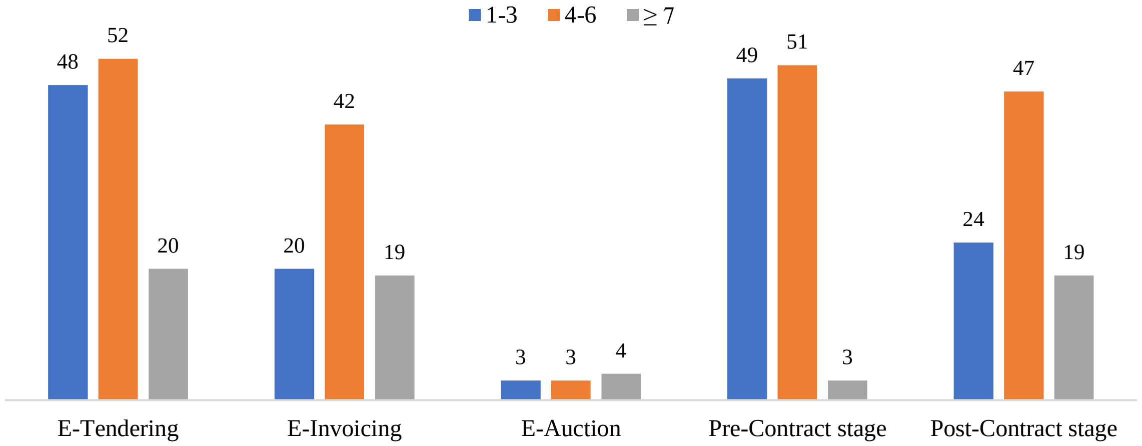

Fig. 2.7 Number of projects with EPSs tools involvement at project stages

2.11 CHAPTER SUMMARY

This chapter presented detailed discussions of the research methodology adopted for this study. Firstly, the rationale for the research design was explained including the research philosophy and the research strategies. Subsequently, the data collection methods were discussed with comprehensive literature review, questionnaire survey and interviews being the most appropriate choice for this study. Further, detailed elaborations and explanations on the data analysis methods employed in this study, that is, mean analysis, factor analysis, FSE, NFS, and AHP were provided. The processes of how these data analysis methods were combined to achieve the aim and objectives of this study were provided in this chapter.

CHAPTER 3 PROCUREMENT IN THE CONSTRUCTION INDUSTRY

3.1 INTRODUCTION

Having discussed the details of the research methodology in Chapter 2, this chapter presents the concept and processes of procurement within the construction industry. Further, the emergence of EPSs, EPSs tools and the sustainability contributions of EPSs in the construction industry are discussed. This chapter draws on previous literature from global perspectives and the infantile literature from the Ghanaian procurement to enhance the understanding of EPSs implementation in the construction industry.

3.2 CONCEPT OF PROCUREMENT

Procurement, in the context of construction, is broadly used to define the processes for the acquisition or purchase of products, construction infrastructure and services by organizations in order to fulfil their duties and responsibilities (OECD, 2016). In generic terms, procurement supports project delivery relationships between buyers and sellers and involves strategic activities such as sourcing, negotiation and coordination (Das et al., 2020; Grilo and Jardim-Goncalves, 2011). With procurement, the objective is to acquire the best possible products, works or services at optimal levels of set criteria desired by the client/project, e.g. quantity, quality, cost and time. Further, procurement provides a structured approach for decision-making by organizations on items from the onset through approval payments to the delivery of the items. Therefore, it has become part of organizational strategy, since it determines the supply chain processes of other organizational operations.

The processes/activities of procurement are the avenues accounting for larger portions of organizational cost or expenditure (Nawi et al., 2017), and has become a crucial area for both private and public sector organizations to improve quality and efficiency in financial spending (Chomchaiya and Esichaikul, 2016). Beyond the financial and economic impact of procurement, the impact of procurement extends to environmental and societal values (Walker and Brammer, 2012; Costa and Tavares, 2014). Specifically, the procurement processes carried out by project organizations to acquire materials and services have due implications, either economically, socially or environmentally (Yu et al, 2020).

3.2.1 Construction procurement (CP) in the construction industry

Within the construction industry, CP refers to the processes used in sourcing, selecting, managing and utilizing resources for a project (Deng et al., 2019; Martins, 2009). The scope of CP processes/activities include, but not limited to, product/item requirement and planning, tendering/bidding, contractor/supplier selection, contract administration, payments and project completion audits. With the construction industry providing the infrastructural support for other industries to grow in national economies, these procurement processes which initiate the management of construction projects, have become crucial for successful delivery of projects (Zhang and Tiong, 2003; Le et al., 2014). For example, the processes employed in selecting a contractor, is a critical activity which has tendencies to determine the project performance. In support, Naoum and Egbu (2016) indicated that increasingly, the fulfilment of these axiomatic criteria, thus cost, quality and time as well as client satisfaction, have been associated with CP.

Several definitions of CP literature include: a strategy to acquire new buildings or facilities from the market to satisfy client's need (Mohsini and Davidson, 1991; Lenard and Mohsini, 1998); the purchase of construction services with the aim of creating a new infrastructure or building for a discrete lifecycle (Choudhury and Sanampudi, 2008); and process of identifying and selecting resource inputs for a project (Department of Business Innovation and Skills, 2012). From these definitions, CP focuses on a framework of processes in acquiring construction-related services and products for a new/existing building or infrastructure throughout its lifecycle by fulfilling specific requirements. Essentially, CP was introduced to structure the procurement processes for projects, in order to increase competition, accountability and promote ethical conduct for the achievement of project value.

Traditionally, the CP processes manage contract administration procedures involving contractors/suppliers for projects using a manual paper-based method (Ibem and Laryea, 2017). The manual paper-based method refers to the heavy reliance on paper documentations and physical interactions for managing contract documentations and processes on a project (Alshawi and Ingirige, 2003). For instance, in the case of tendering for a project which includes tender documents acquisition and submission, both the client and the contractor are faced with huge volumes of paperwork for contract documentation which increases errors, resulting in contractual disputes on projects. Further, contractors are challenged with expending resources on long transportation routes to submit their tender documents for projects. Over the years, this method has proven to be less effective, since it has been continuously beleaguered with many challenges such as the increase in paper documentations, inefficient archiving and slow cycle time of procurement processes in the delivery of projects.

3.2.2 Processes of construction procurement

The processes related to CP generally begin with determining what to procure and end with the successful delivery/confirmation of the product/service to the desired requirements (ISO

10845, 2020). The CP processes have connections to all the stages in a project lifecycle (Ibem and Laryea, 2015). For each project, the CP processes include needs assessment, procurement planning, tendering/bidding, tender evaluation and selection, contract amendments, progress payments, claims management, project completion audits, project delivery and project documentations (Mehrbod and Grilo, 2018; Ruparathna and Hewage, 2013). The successful execution of these processes lies on multiple stakeholders that are distributed across the various stages of the project (Costa and Tavares, 2014). It is worth noting that these procurement activities could occur at different stages of a project. The procurement cycle stages, with regard to a project lifecycle, can be divided into four stages; the pre-contract, contract, contract administration and the post contract stage (Lester, 2006). Fig. 3.1 provides a summary of the CP processes at the different stages of a construction project.

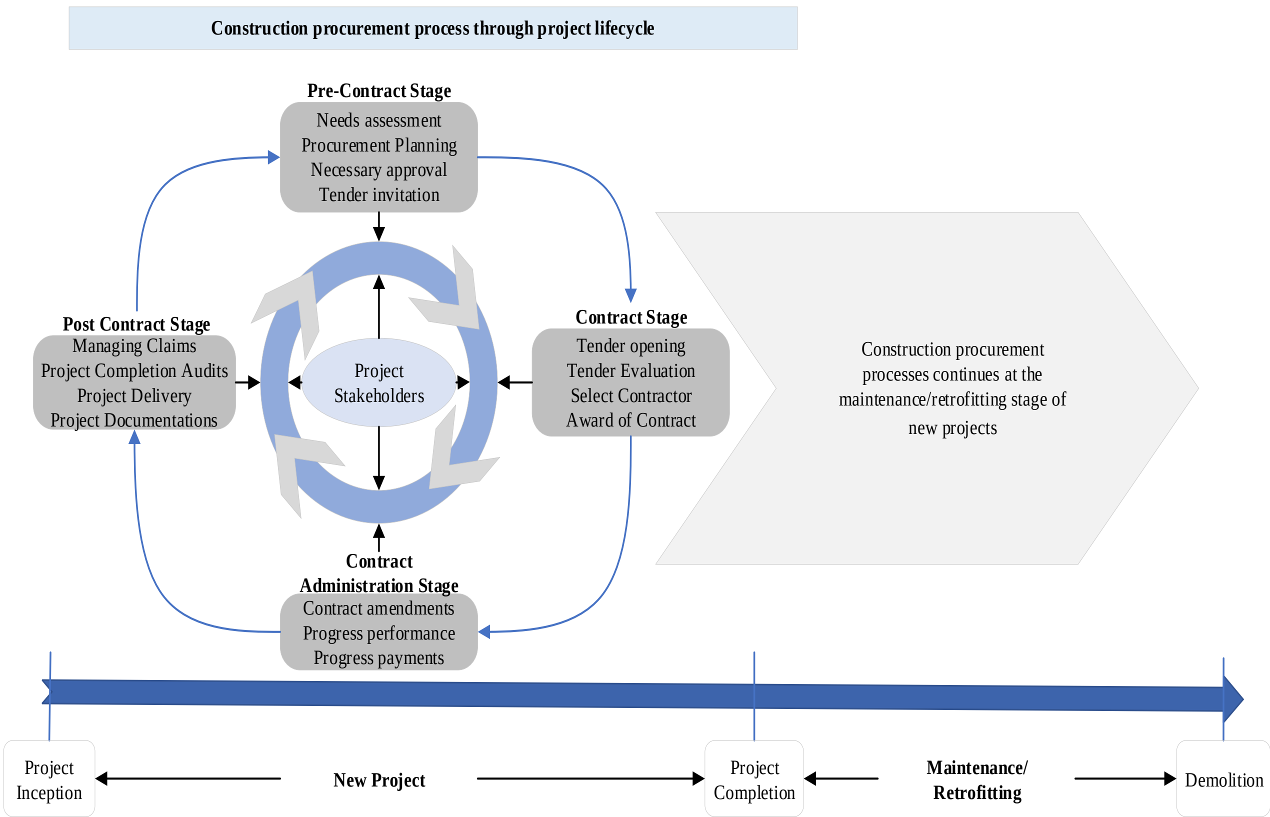

Fig. 3.1 Construction procurement processes in a project lifecycle (adopted from Lester, 2006)

At the pre-contract stage, CP conducts needs assessment to define the needs (i.e. building/infrastructure/product) required and plan for the procurement process for the project. The procurement planning process entails estimating the project cost, specifications, contract documents and obtaining the necessary approvals for the project. The solicitation and receipt of tenders are conducted at the pre-contract stage of the project (Ruparathna and Hewage, 2013). The contract stage comprises the evaluation of the received tenders to select a suitable tenderer/bidder (contractor/supplier) based on pre-determined criteria. Afterwards, the project award is issued to the successful contractor and contract documentations are signed between both parties. During the contract administration stage, the procurement process focuses on contract amendments issues and progress monitoring to facilitate effective delivery and make project payments based on the progress (Lester, 2006). At the post-contract stage, CP addresses issues of final project payments, final contract amendment, check for proof of delivery, completeness of project file documentation and closing out the project. For project teams, each of these processes and activities are critical to ensure effective management of projects for optimal performance. For instance, ineffectiveness in project payments and file documentations could lead to potential disputes among project parties, which could stifle the project's performance.

3.3 EPSs IN THE CONSTRUCTION INDUSTRY

EPSs are described as using internet platforms or online portals to conduct the processes of CP (Teo et al., 2009; Mehrbod and Grilo, 2018; Yu et al., 2020; Ibem and Laryea, 2017). Also, EPSs are related to electronic systems facilitating the administration of contracts between clients and suppliers for the purposes of construction-related services and materials (Yevu et al., 2021a; Li et al., 2002; Betts et al., 2006). With the aim to digitize and automate CP processes in construction supply chain, EPSs have been described using several terminologies including e-marketplace, e-contracting and e-commerce (Hashim et al., 2013). In adopting EPSs, client organizations are presented with online opportunities to communicate and exchange data with contractors/suppliers, while contractors/suppliers in turn, submit tenders/bids through online systems (Santoso and Bourpanus, 2019). With the internet being a major catalyst in many other industries including the construction industry, the need for digitalization has been an increasing demand for organizations to leverage on information technology benefits to achieve competitive advantage (Morgan, 2019; Ruikar et al., 2006). This has necessitated the need to shift from the traditional paper-based method to EPSs systems in the construction industry (Yevu et al., 2021d). To that end, some governments, public agencies and other construction organizations have made efforts to streamline CP with EPSs. Although, the range of EPSs benefits is vast and diverse, compared to other industries such as manufacturing, the construction industry has been lethargic in its adoption (Grilo and Jardim-Goncalves, 2011).

3.3.1 Emergence of EPSs in the construction industry

The emergence of EPSs in the construction industry is attributed to the increasing popularity of the internet since the turn of the twenty-first century (Gunasekaran and Ngai, 2008; Yevu et al., 2021a). Due to the rapid developments in ICTs, organizational processes and workflows became susceptible to construction's revolution shockwave to enhance productivity and efficiency (Zou and Seo, 2006). In effect, Anumba and Ruikar (2002) highlighted the construction industry's inability to escape such huge impacts and pressures to digitize. The need for the construction industry to adopt technological innovations such as EPSs was advocated in Egan's report, which is one of the main drivers of digital innovations in the UK construction industry (Egan, 1998). Egan's (1998) report brought the processes of CP under scrutiny since it indicated that the construction industry could be significantly improved by delivering better service to clients, reducing construction time, cost and errors (Eadie et al., 2007). With contributions above 10% towards national economies, Egan (1998) indicated that the construction industry is too important to be allowed to stagnate, hence, technological innovations were needed in the construction industry. In the US, Tucker (1997) indicated that the target set by the Construction Industry Institute to reduce project cost and delivery by 20% encouraged the absorption of digitization for improvements in CP. While Australian initiatives identified the potential of saving above 25% of time by removing non added value process in the building process, this consequently led organizations to seek improvements in construction processes (Love et al., 2001). Consequently, these targets have led organizations to pursue improvements in the processes of projects, hence EPSs were seen as means that support the achievement of these targets due to their benefits in the CP process (Ribeiro, 2001; McIntosh and Sloan, 2001).

Over the past years, there has been significant interest from organizations such as the EU and the World Bank in encouraging countries to adopt EPS for CP activities to improve transparency and accountability. For instance, the EU has encouraged its member countries and governments to adopt EPSs for procurement (Batenburg, 2007). Although, many countries in the EU have adopted EPSs in other industries such as manufacturing, comparatively, EPSs usage in their respective construction industries in not widespread. The functions of EPSs have evolved since its introduction. From facilitating simple exchange of documents between businesses and organizations, more value has been added to EPSs via combinations of functions in EPSs tools, making it an effective technological management tool for CP.

3.3.2 EPSs tools for CP

EPSs contain several tools that are used to conduct and support different processes/activities of CP at various stages of projects. Depending on the CP processes required by the project, the EPSs tools are designed and developed to automate and transform those processes into online platforms. Hence, the EPSs tools are directly related to the functions/work-packages needed in the procurement process (Yevu et al., 2021a). According to the United Nations Procurement Practitioner's Handbook (UN/PPH, 2006), the main phases for EPSs processes include the e-Notification, e-Submission, e-Evaluation and e-Award, – e-Invoicing and e-Payment. In addition to these phases, EPSs systems provide management tools such as file documentation systems, project auditing system, progress monitoring, project resource and contractor/supplier management systems. Usually, depending on the functions desired from the EPSs, these tools are integrated to produce a work-package system. For instance, electronic tendering tool (e-Tendering) has gained popularity in the construction industry due to its integration of several tools. E-tendering is an integral component of EPSs that combines e-Notification, e-Submission, e-Evaluation, e-Award and is sometimes extended to e-Payment (Grilo and Jardim-Goncalves, 2011). Hence the e-Tendering work-package covers the processes of CP from the pre-contract stage through to the post-contract stage, that is, invitation of tenderers, tender submissions, tender evaluations, tenderer selection and award, and progress payments (Ibem and Laryea, 2015). Fig. 3.2 shows the functions of the e-Tendering work-package.

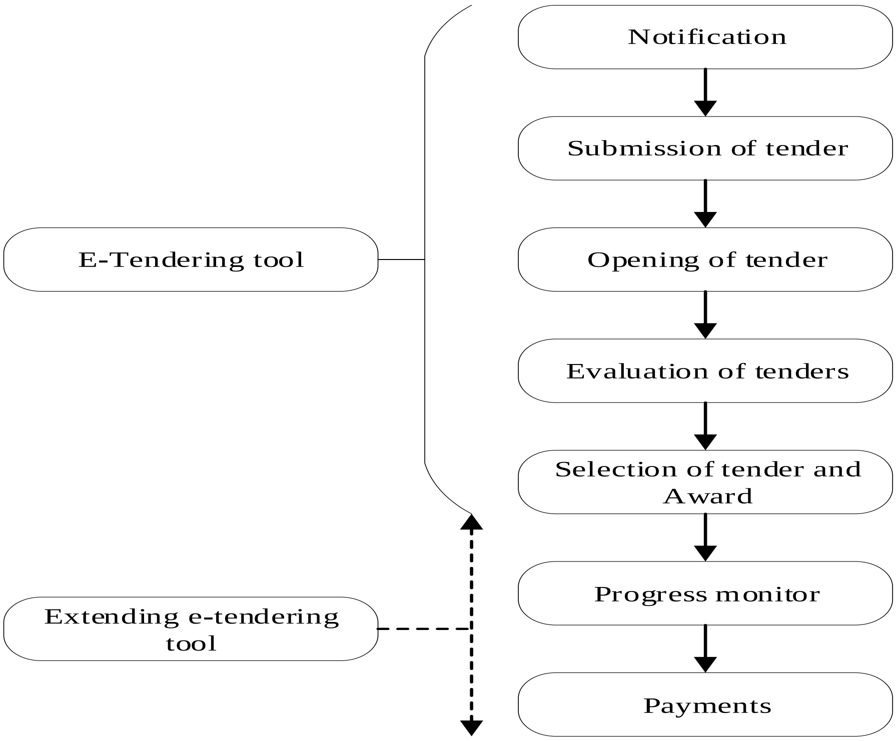

Fig. 3.2 Functions of e-tendering tool

3.3.3 EPSs and sustainability in the construction industry

The benefits and functions of EPSs towards facilitating sustainable procurement (SP) practices in the construction sector have been studied in literature. SP relates to infusing sustainability initiatives and practices into construction procurement through improved quality, environmentally friendly products and services, resource efficiency and cost optimization on lifecycle basis (Roman, 2017; Ramkumar and Jenamani, 2015; Ruparathna and Hewage, 2015). Accordingly, Yu et al. (2020) developed an integration framework to enhance optimal contribution of EPSs to SP initiatives in CP. Walker and Brammer (2012) indicated that EPSs facilitate significant aspects of SP including environmentally friendly practices. Also, Meehan and Bryde (2015) emphasized using EPSs as an enabler for promoting SP practices in the construction supply chains.

Further, it has been noted in literature that the application of EPSs for building projects generates gains that contribute to sustainable construction initiatives. Sustainable construction focuses on responsible creation and management of healthy building environments, considering efficient resource usage and environmental principles (Kibert, 1994). The initiatives of sustainable construction include minimizing resource consumption, maximizing resource reuse, environment protection and pursuing quality in the built environment (Carvalho et al., 2019; Kibert, 1994). Previous studies acknowledged that EPSs significantly improve the efficiency and quality of CP while advancing ecological principles (Yu et al., 2020). Through the benefit of promoting paperless environment, EPSs reduce waste generation, energy and natural resources utilized in the procurement process (Walker and Brammer, 2012). Moreover, the reduction in cost and time with minimized errors from EPSs usage, conserves project resources to improve the quality of CP (Ruparathna and Hewage, 2015; Yevu et al., 2021c). The benefit of improving transparency and collaboration with the use of EPSs facilitates social trust and integrity for sustainable developments. The numerous benefits of EPSs enable CP to contribute to sustainable construction initiatives, considering the future trajectory of digitalization in the built environment.

3.3.4 EPSs adoption elements in the construction industry

Rogers (2010) described innovation as perceiving an idea, practice or object as new by an individual or unit, while adoption is described as the decision to make optimal use of innovation at the best course of action. Further, Damanpour (1991) indicated innovation adoption as generating, developing and implementing new ideas or behaviours with the purpose of contributing to performance or effectiveness of the adopting organization.

Concerning technological innovations, the construction industry is persistently known to be languid towards adopting innovations and among the least digitized industries (World Economic Forum, 2016; McKinsey Global Institute, 2015). This is due to the high fragmented nature of project orientation, difficulty in ascertaining the benefits of complex processes, complexity among multi-stakeholders and dynamic construction business environment (Ozorhon et al., 2016; Sepasgozar et al., 2016; Pan et al., 2018). Hence, the need to fasten the adoption pace has gained attention in literature. Accordingly, various efforts have been made to understand the phenomenon of technological innovation adoption in the construction industry either from established theories or supported by empirical evidence. For instance, some studies explored technological adoption focusing on the technological attributes, organizational characteristics and external attributes that influence a construction organization's potential to innovate (Papadonikolaki, 2018). Ozorhon et al. (2013) explored the management strategies at the organizational or project level to support technology adoption through the innovation process.

Technology is regarded as an essential tool that advances the competitiveness of organizations due to the effects it has on organizational performance and productivity, therefore, these effects will be fully realized if, and when these technologies are widely spread and used among organizations (Oliveira and Martins, 2011). Thus, it is important to understand the elements or determinants of technology adoption and the associated theoretical models that address technology adoption in the construction industry. There are various theoretical models used in literature to examine, understand and summarise factors that influence technology adoption in organizations. However, the prominent theories/models that form the foundational basis for other supplementary models used in the construction industry include diffusion of innovation

(DOI) theory (Rogers, 1995; 2010), technology–organization–environment (TOE) framework (Tornatzky and Fleischer 1990) and the Iacovou et al. (1995) model.

3.3.4.1 Diffusion of Innovation (DOI) Theory

The DOI theory, is described as a theory of how, why and at what rate technology and concepts spread through cultures at the individual and organizational level (Rogers, 1995). It is the most widely used theory and forms the basis for other developed theories of technology adoption (Straub, 2009; Pan and Pan, 2019). The theory is of the view that innovations are communicated through certain channels over time among members belonging to a particular social system (Rogers, 1995). Rogers (1995) highlighted five attributes of innovation that influence adoption; i.e., relative advantage, compatibility, complexity, trialability, and observability. With relative advantage, the individual perceives the technology to be better or worse than other technologies. Hence those technologies perceived to be better are rapidly adopted. Compatibility views innovation as having similar correspondence with existing technologies or concepts. Complexity refers to the difficulties associated with the innovation, which in this study can be related to EPSs barriers. Trialability refers to the accessibility of the technology for experimentation. Observability refers to the availability and visibility of the technology's results or benefits (Rogers, 1995). Individuals possess different degrees of willingness in innovation adoption, and thus the adoption pattern is divided into five parts; innovators, early adopters, early majority, late majority and laggards (Rogers, 1995). For organizations, the innovation process is very complex, since it involves many individuals who may support or oppose the adoption of the innovation in the decision-making process. Hence, the adoption of innovation is related to characteristics at the individual, organizational and external perspectives.

3.3.4.2 Technology–Organization–Environment (TOE)

Tornatzky and Fleischer (1990) developed the TOE model, and it states that an organization's adoption and implementation of technological innovations is influenced by the technological, organizational and environmental context. TOE complements the DOI theory with a third perspective (Pan and Pan, 2019). Since individual, organizational and external characteristics are identical to the technological and organizational context, TOE introduces an important element, the environment. The environment presents both opportunities and constraints to the innovation. It has been widely used to empirically explore and examine factors influencing technological innovations by organizations in research (Oliveira and Martins, 2011). The technological context relates to the attributes of the technology that influences the adoption decision (Tornatzky and Fleischer, 1990). The technological attributes are consistent with DOI theory, with regard to the relative advantage, complexity and compatibility, where the perceived benefits of a particular technology are considered to be better than others (Wang et. al., 2010). These benefits are widely recognised as critical influencers of technological innovations (Pan and Pan, 2019). The organizational context refers to the organizational attributes that can facilitate or hinder the technological adoption. These organizational characteristics include management support, technological readiness and culture of change. The environmental context refers to the operational setting in which an organization interacts with the government and other organizations (Tornatzky and Fleischer, 1990). The external factors, i.e. competitive pressure, regulations, incentives and partner readiness can present challenges or opportunities to the adoption of the technology by the organization. The TOE has good theoretical foundations and supports empirical studies for identifying specific factors from the three contextual spheres for technology adoption across different fields. In literature, theories and models have been combined to address research problems (Li, 2008; Chong et al., 2009). The Iacovou et al. (1995) model is well known for complementing the TOE model in explaining interorganizational systems (IOS).

3.3.4.3 Iacovou et al. (1995) Model.

The Iacovou et al. (1995) model is used to analyse the characteristics of IOS that influence organizations to adopt technological innovations. The model comprises of three elements, perceived benefits, organizational readiness and external pressure (Iacovou et al., 1995). The perceived benefits indicate the organization’s motivation to adopt technology due to the benefits (Van Heck and Ribbers, 1999). The organizational readiness looks at the financial and technological resources of the organization that might influence the adoption decision. External pressure relates to influences from the external business environment, specifically the construction industry or the project environment.

In order to explore the influential forces (i.e. benefits, barriers and strategies) of EPSs adoption in this study, the elements from the DOI, TOE and the Iacovou et al. (1995) model were employed to identify specific factors and elicit more insights on the influential forces surrounding EPSs uptake in the construction industry. Al-Zoubi (2013) suggested deploying multiple approaches in order to improve research outcome and understanding. The DOI and TOE were employed because they are versatile and adaptable to various situations in exploring contextual issues. Further, since the TOE broadens the DOI perspective with the three contexts, it presents a broader scope for exploring and identifying the influential factors to EPSs implementation in the construction industry in Ghana. The elements of perceived benefits and the other external factors (e.g. lack of legal framework) of the Iacovou et al. (1995) model indicates the influences of benefits and barriers in the EPSs implementation process in Ghana.

As indicated by the TOE (Tornatzky and Fleischer (1990) model that the perceived benefits of a technological innovation is a critical influencer technology adoption, this study employs this approach to explore the benefits of EPSs driving their adoption in Ghana.

Drawing on the environmental context of the TOE and the Iacovou et al. (1995) model, and the complexity element of DOI, show that these models suggest there are constraints and opportunities that could influence EPSs adoption aside their influential benefits. As some factors in the theoretical models do not have strong influences in the construction context, context-specific studies have employed pragmatic approaches to investigate new factors that are not directly formulated into these models (Sepasgozar et al., 2018). Such studies provide better understanding of construction technology adoption. Therefore, empirical studies drawing on these theories/models synthesized the main influences of EPSs into benefits, constraints from technological, individual or organizational level and the efforts needed from the individual, organizational and industry level to implement technological innovations (Pan et al., 2020; Sepasgozar et al., 2018; Aibinu and Al-Lawati, 2010). To this end, this study focuses on the benefits, barriers and strategies perspectives for EPSs implementation in the CP in order to comprehensively explore and identify these factors from the Ghanaian context as shown in Fig. 3.3.

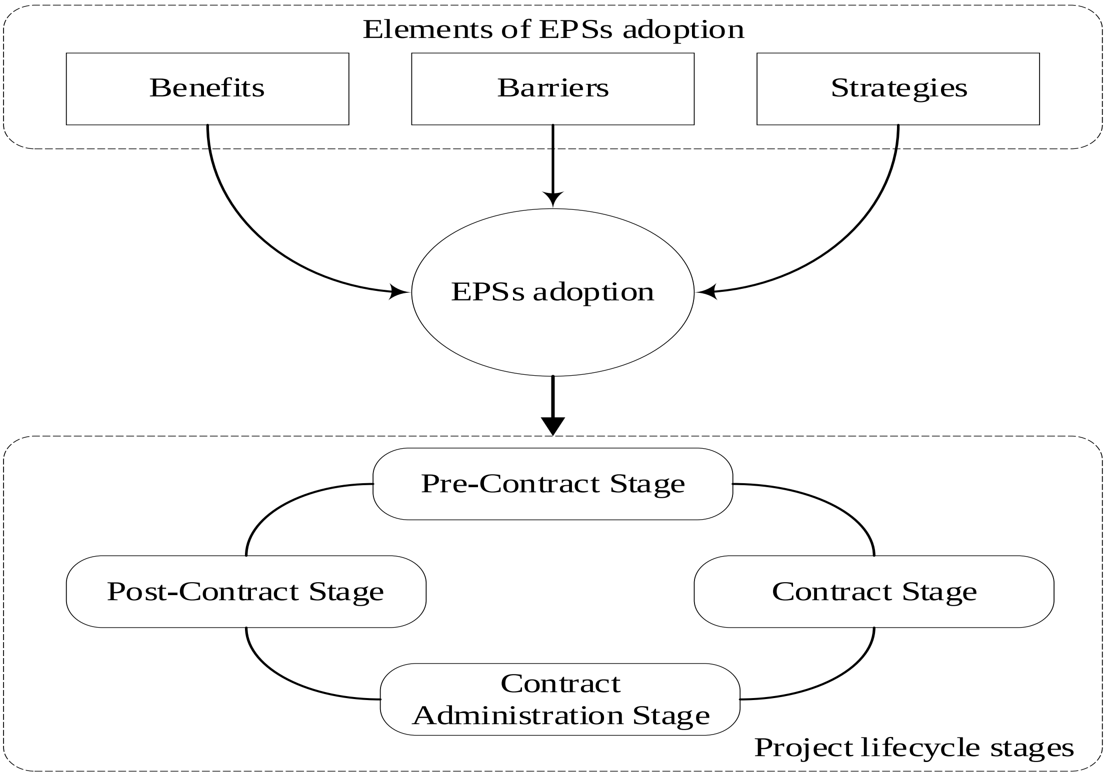

Fig. 3.3 Research framework for the study

3.4 THE DEVELOPMENT OF EPSs IN GHANA

3.4.1 Contextual overview of Ghana

Ghana is a developing country in the West African sub-region (Fig. 3.4), with a population estimated to be about 29.75 million in 2018 and an estimated annual gross domestic products (GDP) growth of about 6.3% reported in 2018 (World Bank, 2018). Within the population landscape, about 51% of the population dwell in urban and peri-urban localities with an increasing average urban population rate of 4.6% and about 49% of the population live in rural and deprived areas (Ghana Statistical Service (GSS), 2014). It is worth noting that the population distribution is largely uneven, and this is as a result of numerous developmental challenges including housing problems and inadequate infrastructure services (GSS, 2014). The increasing rate of GDP growth indicates Ghana's intention to enhance economic growth and sustainable infrastructural developments.

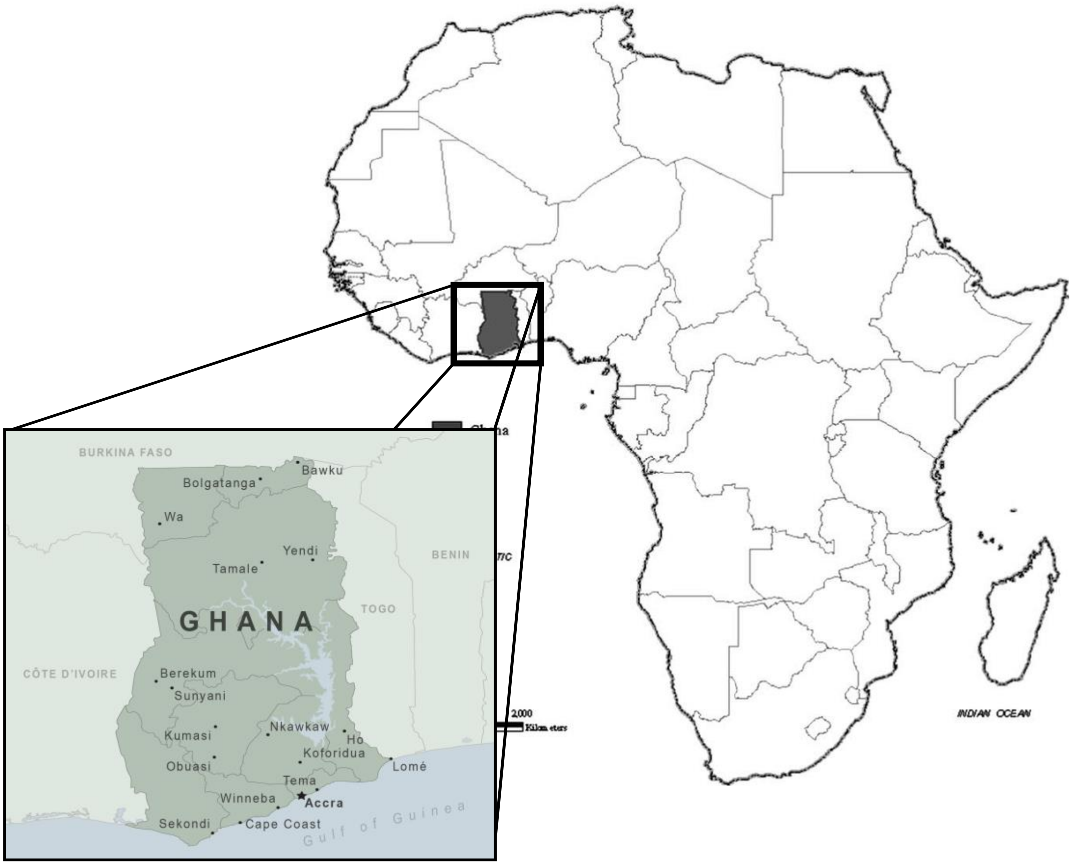

Fig. 3.4 Location of Ghana in Africa

Infrastructure remains a key development priority in order to sustain Ghana's increasing industrial and economic growth as a developing country, as well as achieving SDGs (Ghana Infrastructure Investment Fund (GIIF), 2017). Currently, there is a huge infrastructure gap in both the public and the private sector with regard to housing/building projects, roads/bridges, water projects, factories etc. Efforts at providing such infrastructure or facilities to address the infrastructure gap has resulted in the proliferation of malpractices in the procurement process, procurement delays and inefficiency in the management of projects (Osei-Tutu et al., 2010: Ameyaw et al., 2012). Hence, uncompleted projects and project disputes are common occurrences due to problems attributed of procurement processes. Consequently, the Government of Ghana (GoG), has identified that innovative technological approaches to procurement are critical in order to transform the CP of infrastructure to improve the economic, social and environmental developments in Ghana.

3.4.2 EPSs development in Ghana

The journey of structuring CP in Ghana can be traced to the development of a reform programme in 1996, which was aimed at addressing several identified weaknesses of the existing CP practice by improving efficiency, competition, accountability, transparency and effectiveness on construction projects in the public sector (Ameyaw et al., 2012; Anvuur et al., 2006). At the end of the reform programme, a draft procurement bill was enacted into law in 2003, Public Procurement Act (Act 663) (Anvuur et al., 2006). The procurement law which was later amended (Public Procurement Act (Act 914) 2016) provided an operational framework for public agencies, which also influenced the private organizations since the public sector is the biggest infrastructure buyer in the GCI. The main method used for CP was the manual paper-based method.

Ghana's decision to adopt electronic processes for CP began more than a decade ago, with the purpose of modernizing procurement practices to tackle problems beleaguering the manual paper-based procurement such process delays, increased process cost, ineffective etc. From 2009, numerous attempts have been made by the Ghanaian government to implement EPSs in the procurement processes of projects. However, this process has been beset with many issues limiting its widespread adoption and implementation in the construction industry. Due to the benefits EPSs have brought in other countries such as the UK, Australia and the US, many governments, including the Ghanaian government, have been motivated to adopt it. In recent years, EPSs have been employed in few construction projects in the GCI, although the adoption process has been slow to facilitate optimal achievement of EPSs benefits. Currently, the implementation of EPSs in the GCI focuses on the tendering and contract administration processes for projects.

3.5 CHAPTER SUMMARY

This chapter presents the concept and processes of procurement in the construction industry. In addition, the emergence and tools of EPSs were further discussed from the global and the Ghanaian context to provide comprehensive understanding of the purpose of EPSs in the construction industry. The adoption elements of EPSs adoption are explained in this chapter. Lastly, the procurement terrain alongside EPSs developments in Ghana were discussed.

CHAPTER 4 DRIVERS OF EPSs ADOPTION IN THE CONSTRUCTION INDUSTRY

4.1 INTRODUCTION

Having discussed the processes of CP, the emergence of EPSs, the kinds of EPSs tools and its goal to digitally transform CP processes in the construction industry in the previous chapter, this chapter presents a discussion of the literature on the drivers/benefits that motivate the adoption of EPSs in construction projects. The literature review covers studies that address the driving factors motivating the adoption of EPSs for CP from various stakeholders across the construction industry. The benefits associated to EPSs which encourage their adoption are discussed to provide in-depth understanding of the benefit drivers influencing construction stakeholders' decisions to implement EPSs. This review aids in generating the potential list of benefit drivers for further analysis. In addition, the literature on quantitative evaluations of EPSs benefits is discussed in this chapter.

4.2 IDENTIFICATION OF DRIVERS OF EPSs ADOPTION[3]

Several studies have indicated that there are various drivers/benefits encouraging the adoption of EPSs. To identify the drivers motivating the adoption of EPSs, a systematic literature review technique was adopted (Koc and Gurgun, 2021; Hong et al., 2012; Le et al., 2014). The retrieval of relevant papers for reviewing the drivers/benefits was conducted comprehensively using

[3] This chapter is published in:

Yevu, S. K., and Yu, A. T. W. (2020). The ecosystem of drivers for electronic procurement adoption for construction project procurement. *Engineering, Construction and Architectural Management*, *27*(2), 411-440.

Yevu, S. K., Yu, A. T. W., Darko, A., and Addy, M. N., (2021a). Evaluation model for influences of driving forces for electronic procurement systems application in Ghanaian construction projects. *Journal of Construction Engineering and Management*, *147*(8), 04021076.

construction management journals from Wing (1997) and the powerful search engine – Scopus (Grant and Booth, 2009; Lu et al., 2015). The top 12 journals from Wing's (1997) ranking of journals in construction management were initially adopted since these journals are widely recognized in construction engineering and management (Tiruneh et al., 2020; Lu et al., 2015). The rationale behind this approach was to increase the study's search scope. Subsequently, the Scopus search engine was employed to identify more journals that are relevant. The inclusion criteria for selecting journals indicated that journals must have two or more relevant articles.

After searching and screening the journal publications, a total of 68 relevant papers were considered for the further review analysis (Yevu and Yu, 2020). From analyzing the 68 relevant papers, 61 drivers/benefits were extracted. The comprehensive list of the benefits/drivers with their corresponding references are provided in Yevu and Yu (2020) as shown in Table 4.1. The identified drivers are classified and discussed to enhance in-depth understanding in the following sections.

Table 4.1 Drivers of EPSs implementation in CP identified in literature

EPSs Drivers	References
Reduce process, transaction and administrative cost	[2, 3, 5, 8, 12, 14, 15, 16, 17, 21, 22, 25, 26, 27, 28, 29, 32, 33, 34, 35, 36, 40, 42, 45, 46, 47, 48, 54, 60, 64, 66]
Reduce cycle times for process and transaction	[2, 3, 4, 5, 8, 12, 15, 16, 21, 25, 28, 29, 32, 33, 34, 35, 36, 39, 42, 43, 45, 46, 49, 51, 53, 57, 61, 64, 67]
Improve efficiency and effectiveness in the process	[5, 13, 17, 18, 21, 24, 26, 29, 30, 33, 34, 35, 37, 38, 46, 47, 51, 55, 61, 66]
Fast exchange of information among stakeholders	[5, 9, 11, 16, 18, 20, 26, 40, 43, 49, 50, 51, 61, 63, 65, 67, 68]
Ease of access to information (e.g. tenderers)	[3, 7, 9, 26, 28, 38, 40, 46, 48, 51, 54, 57, 59, 60, 64]
Improve response, accuracy and flexibility of process	[12, 13, 19, 23, 26, 27, 31, 32, 34, 45, 46]
Improved communication with stakeholders	[23, 29, 31, 33, 34, 42, 48, 49, 57, 61, 64]
Increase transparency, fairness and accountability	[3, 5, 14, 21, 24, 29, 33, 39, 45, 49, 66]
Increase competition among contractors/suppliers	[14, 15, 16, 24, 27, 29, 32, 33, 66]
Improve quality of process	[2, 17, 26, 29, 33, 34, 45, 57, 59]
Streamlining and integration of process	[6, 8, 9, 15, 20, 21, 38, 45, 48]

Wider coverage and access to contractors/suppliers	[8, 17, 21, 32, 48, 49, 62, 64]
Error minimization by eliminating manual rekeying	[15, 29, 33, 34, 48, 49, 57, 64]
Reduce staffing	[5, 21, 26, 38, 42, 58, 59, 66]
Enhancing competitive advantage of firm	[2, 28, 29, 36, 42, 44, 45, 48]
Effective monitoring of process (real time)	[15, 18, 26, 28, 39, 48, 63]
Platform for collaboration	[8, 9, 10, 23, 26, 38, 59]
Promoting paperless environment	[24, 28, 48, 49, 64, 66]
Improved benchmarking (market intelligence)	[26, 29, 32, 33, 34, 42]
Government regulation and policy	[7, 37, 39, 47, 51, 55]
Improve integration management of project data	[32, 46, 48, 54, 58]
Improve audit trail and reducing disputes	[46, 48, 49, 57, 61]
Client satisfaction	[15, 17, 26, 46, 49]
Enhance inventory management and archiving	[21, 29, 32, 33, 34]
Developing knowledge skill and ability of employees	[1, 29, 33, 34, 38]
Enhance cost reduction in tender prices	[29, 32, 34, 42]
Ease of addressing queries of contractors	[28, 48, 49, 61]
Cost savings in document management	[32, 42, 49, 61]
Ease of use of technology	[8, 12, 13, 51]
Enhance new contractor entrance and identification	[26, 32, 35]
Knowledge database and preserving corporate memory	[28, 49, 61]
Technological readiness of firm	[13, 14, 15]
Enhance regulatory compliance on contracts	[26, 48, 54]
Top management believes and supports technology	[13, 45, 51]
Provide support for added value services	[16, 30, 66]
Pressure from industry and business partners	[13, 47, 51]
Pressure from customers and public	[13, 47, 51]
Employee motivation to use technology	[13, 52, 53]
Increase trust, confidence and reliability in process	[12, 26, 49]
Compatibility of technology to firm's goals	[8, 12, 47]
Employee views technology as professional credibility	[52, 53]
Effective cost management of procured projects	[32, 55]
Better coordination and integration of contractors	[35, 48]
Peer organization's uptake of technology	[13, 14]
Reduce transportation energy, time and cost	[48, 61]
Government demand for value	[7, 47]
Client's demand for use of technology	[7, 47]
Reduce bid collusion and corrupt practices	[3, 66]
Access to internet intelligent tools for decision-making	[59]
Better specification clarification	[55]
Sustaining future development of firm	[56]
Firm's policy for technology advancement	[44]
Influence of technology champion in the firm	[44]
Improve management of physical project resources	[26]
Increase client involvement in process easily	[49]
Better work opportunities	[46]
Availability of adequacy of technology and internet	[12]
Available expertise of technology	[13]
Maturity of project members and team	[1]

Promoting sustainable goals through technology by firm	[13]
Degree of dispersion among project teams	[1]

Note: **1**. Hosseini et al. (2018); **2**. Al-Yahya et al. (2018a); **3**. Santoso and Bourpanus (2019); **4**. Al-Yahya et al. (2018b); **5**. Wimalasena and Gunatilake (2018); **6**. Mehrbod and Grilo (2018); **7.** Jacobsson et al. (2017); **8**. Hassan et al. (2017); **9**. Khan et al. (2016); **10.** Pala et al. (2016); **11**. Kim et al. (2016); **12**. Ibem and Laryea (2015); **13.** Li et al. (2015b); **14.** Svidronova and Mikus (2015); **15**. Doloi (2014); **16.** Costa and Tavares (2014); **17**. Ibem and Laryea (2014); **18**. Laryea and Ibem (2014); **19**. Tas et al. (2013); **20**. Kang et al (2015**); 21**. Karthik and Kumar (2013); **22.** Bahri et al. (2013); **23.** Grilo and Jardim-Goncalves (2013); **24.** Gardenal (2013); **25.** Eadie et al. (2012); **26.** Kang et al. (2012); **27.** Grilo and Jardim-Goncalves (2011); **28.** Gupta et al. (2011); **29.** Eadie et al. (2011); **30.** Ajam et al. (2010); **31.** Cheng et al. (2010); **32.** Abu-Elsamen et al. (2010); **33.** Eadie et al. (2010a); **34.** Eadie et al. (2010b); **35.** Quesada et al. (2010); **36.** Azadegan and Teich (2010); **37.** Dossick and Sakagami (2008); **38.** Rahim and Singh (2008); **39.** Jaafar et al. (2007); **40.** Castro-Lacouture et al. (2007); **41.** Fox and Skitmore (2007); **42.** Eadie et al. (2007); **43.** El-Diraby (2006); **44.** Peansupap and Walker (2006); **45.** Ruikar et al. (2006); **46.** Zou and Seo (2006); **47.** Dooley and Purchase (2006); **48.** Nitithamyong and Skibniewski (2006); **49.** Ruikar et al. (2005); **50.** Obonyo et al. (2005); **51.** Pearson and Grandon (2005); **52.** Peansupap and Walker (2005a); **53.** Peansupap and Walker (2005b); **54.** Croom and Brandon-Jones (2005); **55.** Wang (2004); **56.** Sarshar and Isikdag (2004); **57.** Nitithamyong and Skibniewski (2004); **58.** Voordijk et al. (2003); **59.** Zhang and Tiong (2003); **60.** Li et al. (2003); **61.** Alshawi and Ingirige (2003); **62.** Lockley et al. (2002); **63.** Yeo and Ning (2002); **64.** Anumba and Ruikar (2002); **65.** Stewart et al. (2002); **66.** Liao et al. (2002); **67.** Tserng and Lin (2002); **68.** Dulaimi et al. (2002).

4.2.1 Classification of drivers for EPSs adoption

To enhance a comprehensive understanding of these drivers, classifying the drivers into respective groups was essential as adopted by Zhong et al., (2019), Lu et al. (2015) and Xiong et al. (2010). Some attempts by previous studies have been made to group the drivers/benefits (see Eadie et al., 2010a; Karthik and Kumar, 2013). For example, Karthik and Kumar (2013) grouped the drivers from their study into five groups: relative performance benefit drivers; financial benefit drivers; perceived supplier benefit drivers; technical benefit drivers and other benefits (i.e. benefits not classified into any of the groups above). Karthik and Kumar (2013) clustered the benefits drivers through the perspective of the process-view approach with the focus on only the managers viewpoint of benefits, but did not consider other driving forces for EPSs adoption. Further, Eadie et al. (2010a) classified the drivers into three, from the lens of typical construction project goals, i.e. time drivers, quality drivers, cost drivers and general drivers (drivers that were not classified into any of the three groups above).

A critical assessment of past literature suggests that the two classifications from Eadie et al. (2010a) and Karthik and Kumar (2013) present a firm foundation that can be adopted for the grouping of EPSs drivers in this study, but additional classifications are required to better describe the dynamic nature of EPSs drivers in the CP. Therefore, this research classified the drivers/benefits of EPSs for CP into seven groupings: external drivers; technological and process level drivers; project level drivers; company level drivers; service satisfaction drivers; individual level drivers and sustainability concept drivers. The classifications of these drivers were based on commonalities among the benefits/drivers and the dimensions/levels at which they operate in construction. In comparing this study's proposed classification of drivers to past attempts, this study integrates driving factors that stems from project goals and the benefits encouraging EPSs adoption at different levels of project procurement. Fig. 4.1 illustrates the framework for the classifications of EPSs drivers. The detailed discussions of these classifications are provided in subsequent subsections.

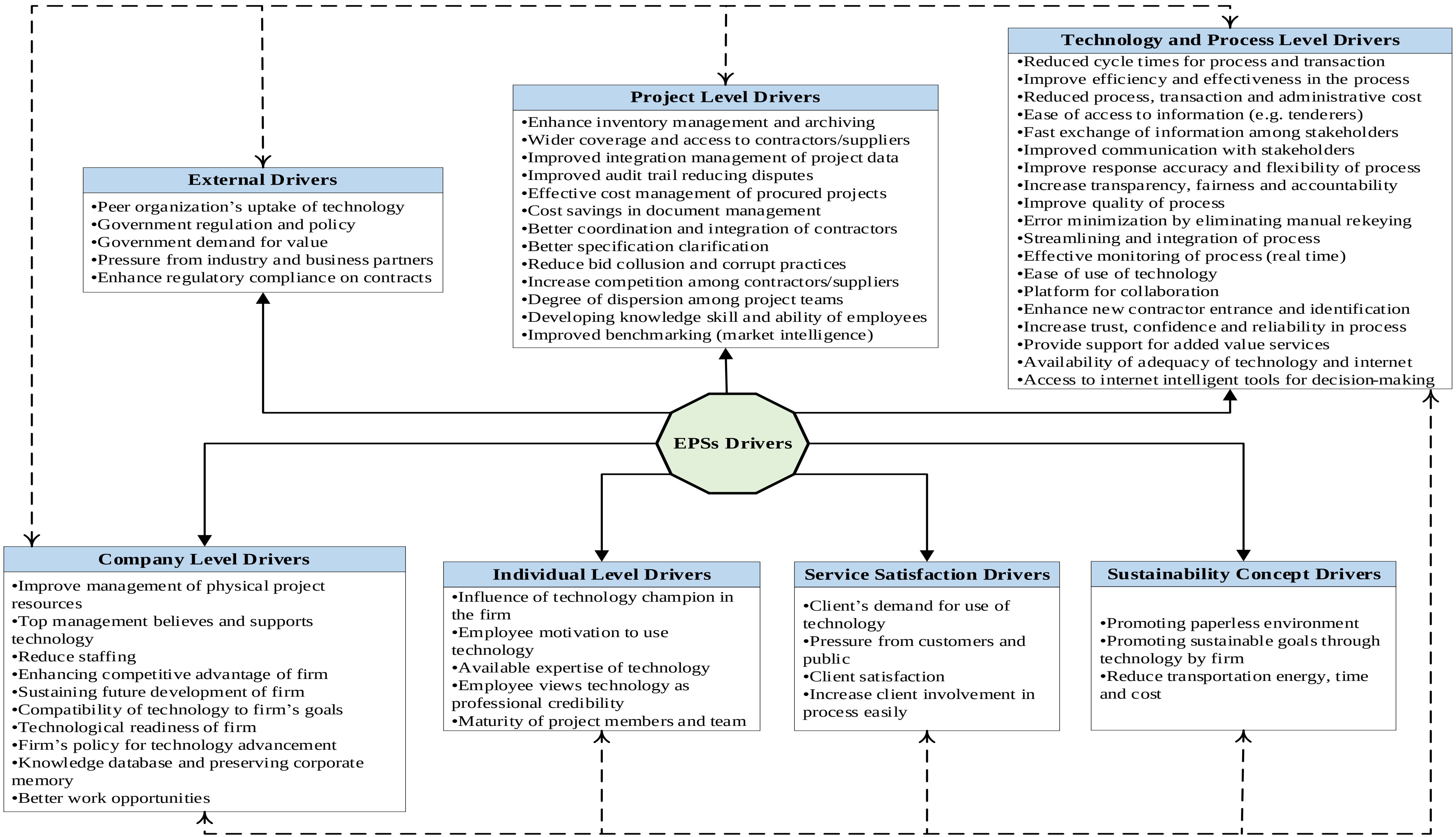

Fig. 4.1 Conceptual framework for EPSs drivers (adapted from Yevu and Yu, 2020).

4.2.1.1 External drivers

External drivers describe factors that are mainly from entities outside of the project organization such as regulatory agencies, government bodies, international organizations and other industry organizations. Based on common relationships, pressure from industry and business partners, government regulation and policy, government demand for value, peer organization's uptake of technology and enhance regulatory compliance on contracts were classified and labelled under external drivers. Government regulation and policy was the driver mostly identified in this classification. Over the past decades, many government initiatives and international agencies have been involved in the promotion of EPS for construction projects (Jacobsson et al., 2017; Dossick and Sagami, 2008). In Europe for instance, the European Union's (EU) initiative to establish an EPSs platform among its member countries began in the second millennium (Strejcek and Theil, 2003; Saastamoinen et al., 2018). This initiative served as motivation for many governments within the EU to further strengthen regulations and policies towards using EPSs for procuring projects. For instance, the UK government in 1998 set out policies to facilitate EPSs among government agencies, business and users (Foley, 2000, Eadie et al., 2010a).

In the US, several federal states have initiated e-commerce into their core business operations in order to deliver government information and projects (Layne and Lee, 2001; Fleming et al., 2010). The study conducted by Dossick and Sagami (2008) realized that the pressure to adopt electronic platforms for coordinating projects was higher in Japan as compared to the US. In Japan, the government has formulated policies to regulate these electronic platforms as a strategy to recover from a long recession (Dossick and Sagami, 2008). Other countries such as Australia, Portugal and Malaysia have their governments pushing for the widespread use of EPSs in construction organizations through policies and regulated frameworks (Jaafar et al., 2007; Costa and Grilo, 2015; Dooley and Purchase, 2006). These policies and regulations by governments stimulate its organizations to take up EPSs when procuring projects. Another factor, thus government demand for value, encourages organizations to seek optimal ways of carrying out projects (Jacobsson et al., 2017). Governments across the globe demand for value on projects with increased efficiency and effectiveness because of the limited availability of resources (Yuan and Yang, 2020; Sullivan, 2010).

An additional factor in this classification is pressure from industry and business partners. The study by Li et al., (2015) and Pearson and Grandon (2005) showed that, organizations that adopted EPSs were influenced by industrial dynamics and pressure from their business partners. The interplay between an organization and its industry is a complex network (Wang et al., 2020; Jacobsson et al., 2017), since organizations have both direct and indirect connections with various stakeholders in the industry. Fulfilling the stakes of these industry players on a project, modifies the approaches and the structures of the organization to adopt improved ways of performing procurement. Peer organization's uptake of technology is another factor influencing organizations to adopt EPSs (Sepasgozar et al., 2018). In China, the study by Li et al. (2015b) provided empirical support of the influence of competitors/rivals/peer organizations on the adoption on EPSs for projects. There is an imitation behaviour among organizations that adopt technology, hence, if one organization adopts EPSs, it positively influences other organizations to adopt it (Sun, 2013). Such imitation behaviour reduces regrets associated with post-adoption because the peer organization's adoption provides suitable justification for the other organization to adopt it (Li et al., 2015b). Svidronova and Mikus (2015) showed evidence that organizations and project managers that adopted EPSs, inspired other project managers to adopt EPSs in CP for projects.

4.2.1.2 Project level drivers

From the review findings, project level drivers can be associated with 13 drivers which include improved audit trail reducing disputes, wider coverage and access to contractors/suppliers, enhance inventory management for project data, increase competitions among contractors/suppliers, reduce bid collusion and corrupt practices etc. (see Fig. 5.1). These driving factors focus on benefits that can be gained when EPSs are applied in project procurement (Yevu and Yu, 2020). Wider coverage and access to contractors/suppliers is one benefit that stakeholders anticipate in using EPSs, in order to achieve better contract value for projects. This also allows larger access to quality contractors and suppliers for partnerships, which would in turn enhance the quality of project delivery (Hassan et al., 2017; Anumba and Ruikar, 2002). The project image and capability are further increased for cooperation with other parties (Nitithamyong and Skibniewski, 2006). This provides the opportunity for the project to increase its spectrum of contractors and suppliers enhancing the decision for a suitable selection of contractor or supplier for the project. Another driver at the project level is improved audit trail and reducing disputes. Studies by Nitithamyong and Skibniewski (2006) and Ruikar et al. (2005) have shown that effective audit trail created by the EPSs platform, has resulted in the reduction of disputes among project teams. Considering the fragmented nature of the project teams, which is easily prone to disputes, efforts or measures that prevent or mitigate the occurrence of disputes have received attention by project managers (Ho, 2016; Hansen, 2018). Hence, project managers are inspired to adopt EPSs in order to ensure effective audit information and avoid disputes which in turn promotes the collaborative environment for project delivery.

Improving the management of project data and portfolio from the beginning of the procurement process is important for project success. ‘Improve integration management of project data’ as a driver, provides the opportunity for data to be integrated across project teams from both design and construction teams (Deng et al., 2019; Zou and Seo, 2006). Different team members participate in the procurement process of projects, which makes it necessary for the integration of procurement information for the project delivery. 'Enhance inventory management and archiving' is another benefit project managers desire for the entire procurement process (Kang et al., 2015; Eadie et al., 2010b). Studies from Eadie et al. (2010b) indicated that enhancing inventory management was a significant motivator for construction professionals to adopt EPSs for projects in the UK. The professionals also indicated that the inconvenience of archiving the process and completed work through the traditional way motivates them to adopt EPSs (Eadie et al., 2010b). The volume of documents exchanged during the procurement process for a project makes it imperative for project managers to adopt technological methods for archiving such data. The cost associated with managing documents on projects motivates project managers to adopt EPSs. Cost savings in document management is one of the factors driving project managers and organizations to adopt EPSs (Santoso and Bourpanus, 2019; Abu-Elsamen, 2010), since it provides a more efficient approach to managing documents compared to the traditional paper-based document management. Abu-Elsamen et al. (2010) in their study, identified that effective cost management of procured projects was one factor that motivated organizations to adopt EPSs. This factor allows the organization to have a better view of their financial portfolio with respect to a larger number of projects. Another benefit of EPSs, that is, 'better coordination and integration of contractors' has also attracted project managers to adopt EPSs for projects (Nitithamyong and Skibniewski, 2006). Integrating the portfolio of numerous contractors or suppliers becomes inefficient when it is paper-based for procurement processes. This has given cause for project managers to adopt EPSs for efficient coordination and integration of contractors and suppliers.

The risk of having procurement malpractices on projects during the procurement process encourages the uptake of EPSs. Studies by Santoso and Bourpanus (2019) and Liao et al. (2002), showed that, one motivation for organizations to adopt EPSs was to reduce bid collusion and corrupt practices. The procurement process in the construction and engineering sector is highly vulnerable to corrupt practices (Transparency International, 2009), hence organizations employ EPSs to curb these corrupt practices. Increase competition among contractors/suppliers is an additional driver that motivates organizations to adopt EPSs for projects. Project managers perceive that increasing the number of competitors for the project, leads to achieving better value for that project (Awwad and Ammoury, 2018). Moreover, EPSs presents the opportunity of accessing bigger coverage of contractors hence, increasing the competitiveness of that project (Doloi, 2014; Gardenal, 2013). This driver received the most attention in this classification with nine studies addressing it. Studies such as Eadie et al. (2011) identified developing knowledge skill and ability of employees as a driver for EPSs. Projects that employ EPSs equip the team members with technological skills and abilities in conducting procurement processes. This stimulates stakeholders to implement EPSs for their projects.

The two other drivers improved benchmarking and degree of dispersion of project teams describes the level at which the organization is informed about the supply market, based on the ease of compilation of data and the characteristics of project teams (Kang et al., 2012; Eadie et al., 2011; Hosseini et al., 2018). These drivers influence the decisions of management to adopt EPSs due to the technological benefits it provides enhancing market search and teamwork across regions.

4.2.1.3 Technology and process level drivers

The technology and process level drivers refer to motivations or benefits for EPSs usage in the procurement processes of projects/products. With 21 drivers identified from literature, this classification has the largest group of drivers. From the findings, reduce process, transaction and administrative cost was the most identified driver for using EPSs in project procurement (see Table 2). Reducing the cost associated with the process of procurement has been a motivation for many organizations in order to save cost without compromising on the quality and effectiveness of the process. Studies such as Santoso and Bourpanous (2019), Svidronova and Mikus (2015) and Doloi (2014) have shown that organizations and project professionals are highly driven to adopt EPSs due to the possible cost savings when implemented in project procurement. For instance, in Svidronova and Mikus (2015) study, about 12% of cost savings was achieved on the tendering process for construction projects by public agencies when EPSs was used. Alshawi and Ingirige (2003) also reported cost savings of 58,130 pounds was achieved when EPSs was used for procuring projects. Another major driver for the adoption of EPSs from literature was reduce cycle times for process and transaction. Project delay is one phenomenon influencing the performance of projects especially project timelines (Mahamid et al., 2011). Any opportunity to accelerate processes in projects draws the attention of project managers, hence, the attraction to adopt EPSs by reducing the time spent in the procurement process. Previous studies by Ibem and Laryea (2015) and Doloi (2014) showed how this ability of EPSs to reduce time had greatly influenced project managers decisions in employing it for projects.

Further motivation for the adoption of EPSs is the fast exchange of information among stakeholders, which also describes the swiftness with which information is shared among project teams. Ruikar et al. (2005) indicated that project organizations that employed EPSs for procuring projects realized an increase in the exchange of information which enhanced the delivery of the project. EPSs present a platform whereby information is shared rapidly to update project teams on the project, which subsequently enhances informed decisions by project managers (Kim et al., 2016). Since the procurement process contributes to initiating a project, efficiency and effectiveness in the process of procurement is vital (Yevu and Yu, 2020). Improved efficiency and effectiveness in the process as a benefit has encouraged the EPSs uptake. The traditional paper-based process of procurement suffered some inefficiencies and exposed lots of ineffectiveness in the process, which has made EPSs attractive for procurement of projects or products (Li et al., 2015b; Tas et al., 2013).

Additional drivers for EPSs adoption are ease of access to information and improved communication with stakeholders. Contractors/suppliers access to information is crucial in the process and the study by Pearson and Grandon (2005) and Wimalasena and Gunatilake (2018) substantiated the interest of organizations to adopt EPSs to ensure easy access to information by contractors/suppliers. Contractors/suppliers are a major part of the project procurement process, hence their access to information relating to the project determines the success of the project (Khan et al. 2016). The use of EPSs ensures that the communication among project teams is stable and effective (Grilo and Jardim-Goncalves, 2013). Due to the complexity of networks within the project procurement process (Khan et al. 2016), improving communication has become important to avoid unnecessary bottlenecks of communication breakdown. Considering the extent to which project cost is determined at the initial stages for a project, transparency, fairness and accountability become key motivations for using EPSs to ensure a sound process. The construction professionals who participated in the study by Eadie et al. (2010a) and Ruikar et al. (2006), indicated that the benefits of increasing transparency, fairness and accountability encouraged them to use EPSs when procuring projects. Studies by both

Kang et al. (2012) and Eadie et al. (2010b) realized that drivers such as improve response, accuracy and flexibility of the process, and improve quality of process were significant benefits that attracted organizations to adopt EPSs. Although the procurement process is usually stepwise, it can also be iterative. This requires the procurement process to be flexible and responsive with accurate information to project teams on the project. The quest for organizations to improve the quality of the traditional paper-based procurement processes has encouraged the adoption of EPSs, since early adopters of the technology observed improvement in the quality of the process (Mehrbod and Grilo, 2018; Zhang and Tiong, 2003).

The implementation of EPSs helps simplify the process for easy integration, hence, 'streamlining and integration of process' as a driver, has gained attention in literature (Mehrbod and Grilo, 2018; Eadie et al., 2010a; Kang et al., 2015). Due to the number of processes required in project procurement, having a platform that integrates it enhances effective decision making. One shortfall of the traditional paper-based procurement was the recurrence of errors due to manual keying of information. On the other hand, one advantage of EPSs which has encouraged its uptake is error minimization by eliminating manual rekeying (Wimalasena and Gunatilake, 2018; Alshawi and Ingirige, 2003; Ruikar et al., 2005). The driver, 'effective monitoring of process (real time)', provides the opportunity for tracking the status of the procurement process in real time, e.g. from invitation to bidding to award of contract (Jaafar et al., 2007). This enhances progress reporting of the process to project teams. Drivers such as platform for collaboration, ease of addressing queries of contractors, enhance cost reduction in tender prices and ease of use of technology have contributed considerably to motivating construction project managers to adopt EPSs (Khan et al. 2016; Ruikar et al., 2005; Eadie et al., 2011; Ibem and Laryea, 2015). Drivers that had less attention from literature at the technology and process level were 'enhance new contractor entrance and identification', 'provide support for added value services', 'increase trust, confidence and reliability in process', 'access to internet intelligent tools for decision-making' and 'availability of adequacy of technology'. Notwithstanding the fact that few studies identified these drivers, they also provide motivations for organizations to adopt the technology.

4.2.1.4 Company level drivers

The company level classification describes drivers that motivate corporate management of construction organizations to adopt EPSs. As shown in Fig. 5.1, 10 driving factors were identified at the company level. One benefit realized with the use of the technology is the reduction in the number of human personnel (Wimalasena and Gunatilake, 2018; Eadie et al., 2007). Reduce staffing was identified by Eadie et al. (2007) as a driver among construction organizations in the UK for the implementation of EPSs. Considering the number of people typically involved in the traditional paper-based procurement, EPSs takes away major portions of the process executed by human personnel. For example, less labour is required for tender document preparation (Liao et al., 2002).

The competitive nature of organizations towards projects has encouraged organizations to seek ways of boosting its prospects in winning projects (Nitithamyong and Skibniewski, 2006). The driver, 'enhancing the competitive advantage of firm', has given organizations the desire to implement EPSs in order to improve the organization's image. Presently, construction organizations function as knowledge-based entities, therefore, to support organizational learning, corporate memory is created to manage the knowledge (Huang et al., 2013). The advantage of having a knowledge database and preserving corporate memory when EPSs is adopted has encouraged organizations to implement it, this is evident in the study by Ruikar et al. (2005). The support of top management towards the adoption of a technology is vital to both the initiative and the usage of that technology. Top management believes and supports technology as a driver, is a stimulator for the organization to seek technological approaches of solving issues (Santoso and Bourpanus, 2019; Pearson and Grandon, 2005).

Prior studies by Hassan et al. (2017) showed that organizations are more motivated to adopt EPSs based on how well it is tailored to their organizational needs and goals. Compatibility of technology to firm's goals as identified from literature exhibits the organizations attraction to take up EPSs. Further, technological readiness of firm, indicates the preparedness of the organization for technology uptake. For instance, in Svidronova and Mikus (2015) study, the organizations were encouraged to adopt EPSs for construction projects because of the information technology sophistication and readiness of the organization. The driver 'firm's policy for technology advancement', inspires management to easily adopt technological innovations such as EPSs (Peansupap and Walker, 2006). Sustaining future development of firm is one incentive for organizations to encourage EPS uptake (Sarshar and Isikdag, 2004). Since organizations dwell in dynamic technological environments, sustaining the processes of the organization, demands aligning to technological improvements. EPSs presents ameliorating opportunities to manage physical resources, hence the driver 'improve management of physical project resources' was recognized in literature (Kang et al., 2012). The anticipation of EPSs offering better work opportunities has similarly inspired some construction organizations to adopt EPSs (Zou and Seo, 2006).

4.2.1.5 Individual level drivers

The individual level of drivers relates to factors that motivate individuals to adopt of EPSs in construction projects. Five EPSs drivers were clustered at this level of classification. From human behaviour perspectives, people have the urge to master their operational environment, thus, to attain some level of competence and control their lives (Murtagh et al., 2016). The driver ‘employee personal motivation to use technology’, describes the desire from individuals or project team members to take up EPSs for procuring projects. This desire could stem from personal characteristics of the individual such as embracing technology, receptive learning skills and good rewards with using technology in the past (Peansupap and Walker, 2005; Li et al., 2015b). Further, the driver ‘employee views technology as professional credibility’, shows that construction professionals perceive that some level of professional credibility is attained when technological innovations are employed in their work process (Peansupap and Walker, 2005).

Another driver at this level is the influence of technology champion in the firm. A technology champion is an individual with high enthusiasm for technology and influences other people to accept such technology (Peansupap and Walker, 2006). The technology champion, which could be the project manager, dedicates much effort encouraging project teams and other individuals to adopt EPSs. Available expertise of technology among project members and employees has driven EPSs to be embraced in organizations (Li et al., 2015b). Individual determination to have expert competence of a technology, inspires the project organization to adopt that technology, since these individuals will ensure that the technology is applied productively and efficiently. While technology champion advocates for the use of EPSs, the technology expertise available looks at how technology capability can be accessible. The maturity of project members and team motivates them to employ a more efficient method in conducting projects (Hosseini et al, 2018). The level of partnership and collaboration existing between the project members increases the interest for these members to adopt EPSs for projects.

4.2.1.6 Service satisfaction drivers

The classification, service satisfaction drivers, refers to clients' demands or customers' desires which in turn motivates EPSs uptake on a construction project. Ruikar et al. (2005) indicated in their study that technology adoption can be client driven. A total number of four drivers were identified for this classification. The client satisfaction driver was the most identified driver in this classification. The desire to perform the procurement process to the satisfaction of the client is a good indicator for the success of the project. For instance, in the study by Jacobsson et al. (2017) and Ruikar et al. (2005), project managers employed EPSs for projects in order to respond to client enquiries faster, hence improving their service to the client. Further, Zou and Seo (2006) identified that organizations were willing to adopt EPSs to provide better construction services to the satisfaction of the client. The second driver, pressure from customers and public, indicates how customers or public advocacy on a subject matter can motivate technology adoption. The pressure from the public through public media towards uptake of EPSs due to its benefits, can influence the organizations to consider adopting it (Dooley and Purchase, 2006). This is because, public advocacy has been currently used as a tool to promote changes in various spheres of both government and private activities (Men and Tsai, 2014). The client's demand for use of technology driver, describes the request made by clients on a project concerning the use of a specific technology (Jacobsson et al., 2017). For example, in the study by Ruikar et al. (2005) a company adopted EPSs because their client insisted its usage on the project. Involving the client in the procurement process also influence the adoption of EPSs on construction projects. The motivation to increase client involvement in the process easily, enables the client to be abreast with the current status of the procurement process (Ruikar et al., 2005). This enhances the client to make input at any stage of the procurement process.

4.2.1.7 Sustainability concept drivers

The sustainability concept drivers classification describes the factors that stimulate a project or organization to consider CP for sustainability contributions (Grandia and Kruyen, 2020). Under this classification, three drivers were identified. Within this classification, promoting paperless environment was the driver mostly identified in literature. Studies by Gardenal (2013), Ruikar et al. (2005) and Nitithamyong and Skibniewski (2006) show that organizations that adopted EPSs experienced the benefit of reducing the total volume of papers used for the procurement process. Reducing the volume of papers used for procurement has an environmental value considering the number of trees that could be saved (Gardenal, 2013). Although this contribution to sustainability is relatively considerable globally, some organizations view it important and have made commitments towards promoting paperless environment (Ruikar et al., 2005). Promoting sustainable goals through technology by firm is another driver encouraging the adoption of EPSs (Li et al., 2015b). Policies by firms to use technology to promote sustainability provides exploration opportunities for the organization to contribute towards sustainability. Reduce transportation energy, time and cost as a driver for EPSs for procuring projects (Alshawi and Ingirige, 2003), inspire project managers and organizations to contribute to environmental sustainability. Although, reducing the transportation energy, time and cost associated with the procurement process can be allocated to the cost and time benefits of adopting EPSs, conserving the amount of energy expended on transportation has some valuable contribution towards environmental sustainability.

4.2.2 Benefit drivers of EPSs in construction industry

To identify the benefit drivers from the numerous drivers listed, a critical evaluation of the driver factors was conducted. Benefit drivers refer to drivers denoting gains, advantages or improvements that EPSs bring as a result of its characteristics, attributes or functions. As earlier stated, the benefits of a given technological innovation are key influences that attract organizations or individuals for its uptake, and further provides the desired competencies of the technology. Therefore, after careful examination of the drivers list produced, 26 benefit drivers were employed for the study's survey in Ghana. Table 4.2 presents the 26 synthesized benefits as relevant driving forces (DF) from the list of drivers for EPSs implementation.

Table 4.2 List of DFs identified for EPSs application with references

Code	Driving forces	References*
DF01	Reduce process, transaction and administrative cost	[2]; [4]; [5]; [6]; [7]; [20]; [21]; [22]; [25]; [26]; [27]
DF02	Reduce cycle times for process and transaction	[2]; [4]; [5]; [8]; [9]; [23]; [24]; [25]; [26]; [27]
DF03	Improve efficiency and effectiveness in the process	[4]; [7]; [11]; [12]; [13]; [14]; [15]; [27]; [28]
DF04	Fast exchange of information among stakeholders	[6]; [16]; [18]; [19]; [20]; [27]
DF05	Ease of access to information and management of project data	[8]; [14]; [16]; [17]
DF06	Improve response, accuracy and flexibility of process	[4]; [10]; [11]; [18]; [25]
DF07	Improved communication with stakeholders	[1]; [4]; [14]; [18]; [19]
DF08	Increase transparency, trust and reliability of the process	[2]; [23]; [25]; [27]
DF09	Increase competition among contractors through wide coverage	[5]; [7]; [26];
DF10	Improve quality of process and error minimization	[5]; [7]; [16]; [19]; [23]
DF11	Streamlining and integration of process	[3]; [4]; [14]; [26]
DF12	Reduce staffing	[8]; [16]; [23]; [26]
DF13	Enhancing competitive advantage of firm	[5]; [8];[16]
DF14	Effective monitoring of process (real time)	[5]; [8]; [16]; [21]
DF15	Platform for collaboration and added value services	[4]; [13]; [14]; [26]
DF16	Promoting paperless environment	[4]; [8]; [9]; [12]; [21]
DF17	Improved audit trail and accountability	[2]; [4]; [21]; [27]
DF18	Client satisfaction	[4];[5]; [9]
DF19	Enhance inventory/archiving and document management	[4]; [9]
DF20	Develop knowledge and technological skills of employees	[1]; [8]; [11]
DF21	Knowledge data base and preserving corporate memory	[8]; [9]; [16]
DF22	Enhance regulatory compliance on contracts	[4]; [16]; [17]; [28]
DF23	Reduce transportation energy resources	[17]; [21]
DF24	Reduce bid collusion and corrupt practices	[4]; [17]; [22]; [27]
DF25	Access to internet intelligent tools for decision-making	[4]; [6]; [13[; [25[; [26]
DF26	Better working opportunities	[11]; [16]; [21]

*[1] Hosseni et al. (2018); [2] Santoso and Bourpanus (2019); [3] Mehrbod and Grilo (2018); [4] Yevu and Yu (2020); [5] Doloi (2014); [6] Costa and Tavares (2014); [7] Ibem and Laryea (2014); [8] Gupta et al. (2011); [9] Ruikar et al. (2005); [10] Grilo and Jardim-Goncalves (2011); [11] Li et al. (2015b); [12] Gardenal (2013); [13] Ajam et al. (2010); [14] Khan et al. (2016); [15] Kim et al. (2016); [16] Kang et al. (2012); [17] Jacobsson et al. (2017); [18] Tas et al. (2013); [19] Kang et al. (2015); [20] Castro-Lacouture et al. (2007); [21] Nitithamyong and Skibniewski (2006); [22] Liao et al. (2002); [23] Karthik and Kumar (2013); [24] Eadie et al. (2010); [25] Ibem and Laryea (2015); [26] Hassan et al. (2017); [27] Wimalasena and Gunatilake (2018); [28] Dossick and Sakagami (2008).

4.2.3 Knowledge Gaps

From the review of literature on EPSs drivers, it was observed that studies exploring the influential forces of EPSs drivers/benefits clusters needed to stimulate the adoption climate were lacking in EPSs literature. More importantly, there is lack of knowledge on the grouping influences of these benefit drivers in creating a suitable climate for the implementation of EPS in the construction industry. This is necessary in order to determine which benefit drivers motivate EPSs adoption, considering that the benefits of a given technology have been identified to stimulate technology adoption from several countries with different contextual environments. Especially, considering that the conditions in developing countries like Ghana are different from that of developed countries in the context of socio-economic settings. Regarding the high demand for infrastructure and development in developing countries, it is necessary to identify the benefit drivers in order to know how to stimulate EPSs uptake in CP.

4.3 BENEFIT ASSESSMENT FOR EPSs[4]

The measurement of benefits from an IT implementation on an organization or project is gaining research attention despite it being in the nascent stage (Zwikael et al., 2018; Yevu et al., 2020). The concept of benefit measurement is aimed at ensuring that the potential or promised benefits of IT implementation projects are actually realized (Terlizzi et al., 2017). To ensure IT (including EPSs) adds value to the project, the benefits have to be properly defined and measured (Marnewick, 2016; PMI, 2013). This research area emerged from concerns about the low achievements from the anticipated benefits of IT investments (Esteves, 2009).

[4]This section is partially reported in Yevu, S. K., Yu, A. T., Tetteh, M. O., and Antwi-Afari, M. F. (2020). Analytical methods for information technology benefits in the built environment: towards an integration model. *International Journal of Construction Management*, 1-12.

Although this area is emerging, terms such as benefit measurement and benefit evaluation have been associated with this study area.

Considering the capital investments needed for EPSs adoption, organizations and project teams are concerned with identifying and measuring the benefits to ensure EPSs investments deliver satisfactory value (Kim et al., 2010; Silva et al., 2014). Several studies have indicated the phenomenon of organizations and project teams not attaining the anticipated benefits of IT. Hence, previous studies have explored various ways of measuring the benefits of different IT systems in the built environment (Zwikael et al., 2018; Daulatkar and Sangle, 2016; Abdul Kareem and Abu Bakar, 2013), since the use of gut feelings or intuitive assessments provide insufficient motivations for IT adoption (Sacks, 2004). Chang et al. (2017) indicated that literature is replete with studies promoting the benefits of IT systems for construction purposes but studies measuring these benefits are limited. Therefore, momentum could be lost if there are no supportive evidence of IT benefits in the long term. Measuring the benefits of IT has been a difficult challenge (Silva et al., 2014). The use EPSs for projects present a plethora of benefits as earlier indicated which serves as the motivation for the adoption of EPSs in the built environment (Terlizzi et al., 2017).

Since the benefits of EPSs are the main motivators for its adoption in the construction industry, the use of gut feelings to assess the realization of these benefits does not enhance quantifiable evidence to encourage other stakeholders for widespread adoption. Moreover, identifying EPSs benefits that could be quantitatively measured have not been the subject of attention in literature. This poses challenges since many other countries are yet to adopt it. Hence, developing a quantitative priority assessment criteria for EPSs benefits would facilitate the evaluation of benefits in the implementation and usage of EPSs. Further, this would allow efforts towards improving EPSs systems to be effective with regards to its performance given the project situation.

4.3.1 Knowledge gaps

Though EPSs has been in existence over the years, studies on its benefits measurement or evaluation are limited in literature. Further, identifying EPSs benefits that could be quantitatively assessed from their benefit categories are scarce in literature. Addressing this gap contributes to EPSs knowledge on which benefits are more feasible and preferred for quantitative assessment in GCI.

4.4 CHAPTER SUMMARY

This chapter presented a detailed discussion of the literature on EPSs drivers/benefits in the construction industry. The review shows the myriad benefits/drivers motivating the adoption of EPSs. This chapter presents the foundation for exploring benefits of EPSs and to evaluate the quantitative assessments of EPSs benefits in the construction industry.

CHAPTER 5 BARRIERS AND PROMOTION STRATEGIES OF EPSs ADOPTION IN THE CONSTRUCTION INDUSTRY

5.1 INTRODUCTION

The previous chapter expounded on the drivers/benefits motivating the uptake of EPSs in the construction industry and the potential quantitative assessment of EPSs benefits. However, despite the promising benefits of EPSs, barriers to its widespread adoption still exist. Hence, this chapter presents an in-depth discussion of literature on the barriers influencing the use of EPSs in CP. The presence of these barriers makes it imperative for the identification of strategies that promote EPSs implementation on construction projects. Thus, the present chapter focuses on the various barriers and strategies regarding EPSs implementation from various countries and governments within the construction industry.

5.2 BARRIERS TO THE ADOPTION OF EPSs[5]

Within the construction industry, the anticipated boom of EPSs adoption for CP processes have suffered many setbacks in its implementation (Isikdag, 2019; Liu et al, 2018; Jacobsson et al., 2017; Aibinu and Al-Lawati, 2010). For instance, Wimalasena and Gunalitake (2018) identified issues such as resisting the change process for EPSs uptake, tampering with documents and lack of trust and confidentiality for the EPSs as barriers hindering the use of EPSs. Similarly, Eadie et al. (2012) reported factors such as the lack of legal regulations and the high financial cost of implementation hampering the adoption of EPSs.

[5] Reported in Yevu, S. K., Yu, A. T. W., and Darko, A. (2021). Barriers to electronic procurement adoption in the construction industry: a systematic review and interrelationships. *International Journal of Construction Management*, 1-15.

A systematic review of literature was carried out to identify the barriers to EPSs adoption in the built environment. A comprehensive search process, thus journals in Wing (1997) and the search engine – Scopus (McNamara and Sepasgozar, 2021; Lu et al., 2015), were used to retrieve relevant studies for the literature review. The keywords used in the search to obtain papers include electronic procurement, e-procurement, e-commerce, e-tendering, barriers, challenges, construction procurement and construction industry. A careful review of the title, abstract and full text of the papers initially retrieved was conducted to identify papers that discuss the barriers to EPSs adoption and implementation for inclusion. Throughout the search process, a total of 61 relevant papers were considered valid and relevant. Table 5.1 provides the barriers identified with codes assigned to them (Alruqi and Hallowell, 2019). This approach was chosen because it enables themes (i.e. barriers) reported in the research papers to be identified, cross-referenced and categorized (Bengsten 2016). Table 5.2 presents a summary of the barriers identified to EPSs adoption from literature with their respective reference sources and the frequency of identification per reference source using the barrier codes. These barriers describe the issues hindering the implementation of EPSs and causing the rate of adoption to be slow in the construction industry, hence it is important to understand the nature of these barriers.

Table 5.1 Identified barriers to EPSs uptake

Code	EPSs Barriers	Explanation of the barriers in the context of this study
Br1	Perceive technology as disruptive	The degree to which an individual or organization view EPSs technology as a distraction and unsuitable for procurement.
Br2	Resistance to change	Refers to activities taken by individuals or groups to oppose the change process.
Br3	Experiencing the shortcomings of the technology	Includes experiencing deficiencies with EPSs and advocating against it.
Br4	Electronic authentication and authorization issues	This includes issues such as proof of intent, electronic signatures, valid authorization and authentication of documents.
Br5	Attitude and behaviour	Refers to inherent actions or emotions of individuals or organizations to impede EPSs uptake. This includes the feelings and norms of individuals, organizations and industry towards EPSs uptake.
Br6	Unreliable internet service and power supply	This includes poor internet connection, services and interrupted power supply.

Br7	Violations of data integrity	Includes unapproved access to data, viewing of data and tampering of documents.
Br8	Lack of trust and confidentiality	Includes lack of effective security of documents, breaching confidentiality and the lack of trust that the system is secured against cyber hacks and virus attacks.
Br9	Lack of information technology (IT) infrastructure and capability	This refers to unavailable or limited IT infrastructure resources.
Br10	Lack of legal rules and regulations for EPSs	Refers to non-existence of rules and regulations to support EPSs uptake. Includes lack of rules to address disputes in EPSs.
Br11	Possibility of data loss and system errors	This refers to incorrect assembly of documents and losing data through exchange of documents.
Br12	Lack of awareness of EPSs technology	Unaware of EPSs technology and its potential benefits.
Br13	Reluctance to update systems and guidelines for integrating EPS	Refers to unwillingness to update systems and procurement guidelines to accommodate EPSs.
Br14	Lack of technical expertise/skills available	Includes the lack of knowledge, skills and experts to manage EPSs.
Br15	Lack of user friendliness and flexibility	Refers to cumbersome systems not easy to use. It includes lack of clarity and simplicity in process.
Br16	High cost of investment	Includes initial cost for EPSs technology, maintenance cost, cost of hiring and training personnel and cost of internet service.
Br17	Lack of access to EPS technology	Refers to EPSs technology not readily available to organizations.
Br18	Fear of reducing bribery and corruption	Refers to specific individuals (cronies) hindering EPSs uptake to encourage corrupt practices.
Br19	Fear for job loss	Refers to the perception of losing jobs through the reduction of human activities in the process.
Br20	Lack of clear exemplary firms achieving benefits	Refers to non-achievement of benefits by firms who adopted EPSs.
Br21	Low level of personnel training	Refers to the lack of technological education and capabilities of personnel.
Br22	Lack of management support	Refers to the absence of leadership commitment for EPSs adoption.
Br23	Unreadiness of business partners	This includes the unreadiness of organizations, contractors and stakeholders to adopt EPSs.
Br24	Uncertainty in EPSs technology selection	This refers to the lack of proper evaluation of procurement processes to guide the selection of EPSs for implementation.
Br25	Fear of being driven by technology	Refers to the wariness of aligning organization’s decisions and values due to technological dynamics.
Br26	Other competing initiatives of the firm	Refers to the low priorities assigned to the EPSs with respect to other initiatives of the organization.
Br27	Lack of electronic contract enforcement	This refers to the non-implementation of electronic contract laws on the procurement process.
Br28	Lack of awareness of best practice solutions	This refers to the limited access to benchmark practices for EPSs implementation.
Br29	Lack of corporate strategy for EPSs adoption	Refers to the lack of organizational goal to adopt EPSs.
Br30	Fear of unreliable EPSs system	Refers to the perception or feeling that EPS is not dependable.
Br31	Risk of technology immaturity and compatibility	This relates to the uncertainty in the maturity of EPS compared to industry demands and advancement.
Br32	Lack of integration and interoperability	This relates to the lack of interoperability between EPSs and other technologies.
Br33	Partial technological compliance by staff	This refers to the practice of resorting to traditional paper-based process while using EPSs process by staff to address issues.
Br34	Lack incentives for EPSs adoption	This refers to the absence of incentives to motivate individuals, and organizations to adopt EPSs.

Table 5.2 Barriers to EPSs adoption in literature

Barrier	References																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	F
B1	X			X					X													X									4
B2	X	X		X	X			X	X	X		X				X		X			X	X	X	X				X	X	X	17
B3	X															X						X				X					3
B4		X								X													X					X		X	5
B5	X		X	X			X		X					X			X					X		X							9
B6		X	X	X						X														X				X			6
B7	X																						X					X		X	4
B8		X		X				X		X	X					X			X				X	X			X	X	X	X	13
B9		X		X			X			X								X				X		X					X		8
B10		X		X				X		X									X				X			X				X	8
B11		X								X												X	X							X	5
B12		X																					X							X	3
B13		X																													1
B14		X					X	X	X	X											X	X	X	X		X		X	X	X	13
B15		X																					X			X		X		X	5
B16		X		X		X	X	X	X	X		X	X				X	X		X			X	X				X	X	X	17
B17				X																			X							X	3
B18				X																											1
B19				X																											1
B20						X			X	X					X								X							X	6
B21								X		X							X														3
B22									X			X						X			X	X	X						X	X	8
B23												X					X			X	X		X					X	X	X	8
B24															X																1
B25																						X									1
B26																							X							X	2
B27																							X							X	2
B28																							X		X					X	3
B29																													X		1
B30																															0
B31																							X						X	X	3
B32																							X	X					X	X	4
B33																															0
B34																	X														1

Note: F – Frequency of barrier identified.

References: 1= Liu et al. (2018); **2**= Wimalasena and Gunatilake (2018); **3**= Jacobsson et al. (2017); **4**= Ibem and Laryea (2017); **5**= Pala et al. (2016); **6**= Khan et al. (2016); **7**= Lines et al. (2017); **8**= Kim et al. (2016); **9**= Ozorhon et al. (2016); **10**= Ibem and Laryea (2015); **11**= Ibem and Laryea (2014); **12**= Zunk et al. (2014); **13**= Laryea and Ibem (2014); **14**= Tas et al. (2013); **15**= Kang et al. (2013); **16**= Costa and Tavares (2013); **17**= Wong and Zhang (2013); **18**= Altuwaijri et al. (2012); **19**= Eadie et al. (2012); **20**= Ren et al. (2012); **21**= Kang et al. (2012); **22**= Sheriff et al. (2012); **23**= Eadie et al. (2011); **24**= Oyediran and Akintola (2011); **25**= Jacobsson and Linderoth (2010); **26**= Adriaanse et al. (2010); **27**= Cheng et al. (2010); **28**= Aibinu and Al-Lawati (2010); **29**= Abu-ElSamen et al. (2010); **30**= Eadie et al. (2010a).

Table 5.2 Barriers to EPSs adoption in literature (*continued*)

Barrier	References																															
	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	F	TF
Br1										X										X												2	6
Br2	X	X	X		X		X			X		X	X	X							X			X		X	X				X	14	31
Br3																																0	3
Br4	X		X																								X				X	4	9
Br5			X					X				X					X				X					X	X	X		X	X	10	19
Br6			X							X									X													3	9
Br7	X																															1	5
Br8	X				X	X	X	X	X	X				X	X		X	X	X		X	X		X		X	X		X	X	X	20	33
Br9								X	X			X					X			X								X		X	X	8	16
Br10	X		X		X	X		X									X				X									X		8	16
Br11	X				X				X																							3	8
Br12	X									X																					X	3	6
Br13														X																		1	2
Br14	X		X		X			X		X			X	X						X			X					X			X	11	24
Br15	X						X																									2	7
Br16	X				X			X			X		X		X		X							X						X	X	10	27
Br17	X								X	X							X				X	X	X									7	10
Br18																																0	1
Br19		X																													X	2	3
Br20	X				X					X			X								X				X					X	X	8	14
Br21					X				X	X								X		X			X	X				X		X	X	10	13
Br22	X	X	X			X		X	X	X	X	X	X																			10	18
Br23	X	X						X		X			X	X	X			X														8	16
Br24																																0	1
Br25																																0	1
Br26	X																															1	3
Br27	X																															1	3
Br28	X																															1	4
Br29				X									X															X			X	4	5
Br30														X							X	X								X		4	4
Br31	X					X		X	X	X				X												X					X	8	12
Br32	X					X		X	X						X	X					X	X			X	X				X		11	15
Br33						X											X															2	2
Br34					X																											1	2

Note: F – Frequency of barrier identified, TF – Total frequency of barrier identified.
References: 31= Eadie et al. (2010b); **32**= Lou and Alshawi (2009); **33**= Dossick and Sakagami (2008); **34**= Hua (2007); **35**= Williams et al. (2007); **36**= Wang et al. (2007); **37**= Jaafar et al. (2007); **38**= Eadie et al. (2007); **39**= Nitithamyong and Skibniewski (2006); **40**= Peansupap and Walker (2006); **41**= Boonstra (2006); **42**= Ruikar et al. (2006); **43**= Zou and Seo (2006); **44**= Rankin et al. (2006); **45**= Dooley and Purchase (2006); **46**= Obonyo et al. (2005); **47**= Ruikar et al. (2005); **48**= Croom and Brandon-Jones (2005); **49**= Chan and Leung (2004); **50**= Sarshar and Isikdag (2004); **51**= Nitithamyong and Skibniewski (2004); **52**= Kong et al. (2004); **53**= Reddick (2004); **54**= Voordijk et al. (2003); **55**= Zhang and Tiong (2003); **56**= Alshawi and Ingirige (2003); **57**= Elliman and Orange (2003); **58**= Sarshar et al. (2002); **59**= Yeo and Ning (2002); **60**= Anumba and Ruikar (2002); **61**= Love et al. (2001).

5.2.1 Categorization of barriers identified in literature

From Table 5.2, various barriers from the construction industry have been identified in literature. Studies such as Eadie et al. (2010a) and Love et al. (2001) have categorized some barriers based on their empirical studies. These categorizations provided the theoretical foundation for the proposed categorization in this study, which has the aim of presenting a broader perspective of the barriers across countries for better understanding. This approach of employing previous studies as theorical foundations to better describe a phenomenon has been adopted by similar review studies (Luo et al., 2017; Abotaleb and El-adaway, 2018). Webster and Watson (2002) emphasized that a literature review presents the opportunity to gather findings from many places to provide firm insights into a phenomenon. The conceptual categorization integrates the findings from previous studies to present a comprehensive approach for understanding the barriers, which may enhance development of effective strategies to mitigate the barriers to the adoption of EPSs in the construction industry.

The proposed categorization entails: organizational barriers; technological barriers; cultural barriers; and legal and security barriers. These categorizations were derived from the definitions and the explicit forms of commonality existing among the identified barriers in literature (Nasirian et al., 2019). Fig. 5.1 summarizes the categorizations and their respective barriers. Likewise, from Fig. 5.1, the interrelationships among the categorises are depicted. It is important to note that barriers within one category may also be interrelated and impact each other or other barriers in another category. For instance, the 'fear for job loss' barrier in cultural barriers category may have interrelations and impact the 'reluctance to update systems and guidelines for integrating EPSs' barrier in the legal and security barriers category. The interrelationships present complex structural networks hindering the adoption of EPSs which needs to be understood when developing strategies to mitigate the barriers to EPSs in the construction industry. The categories are discussed in the subsequent sections.

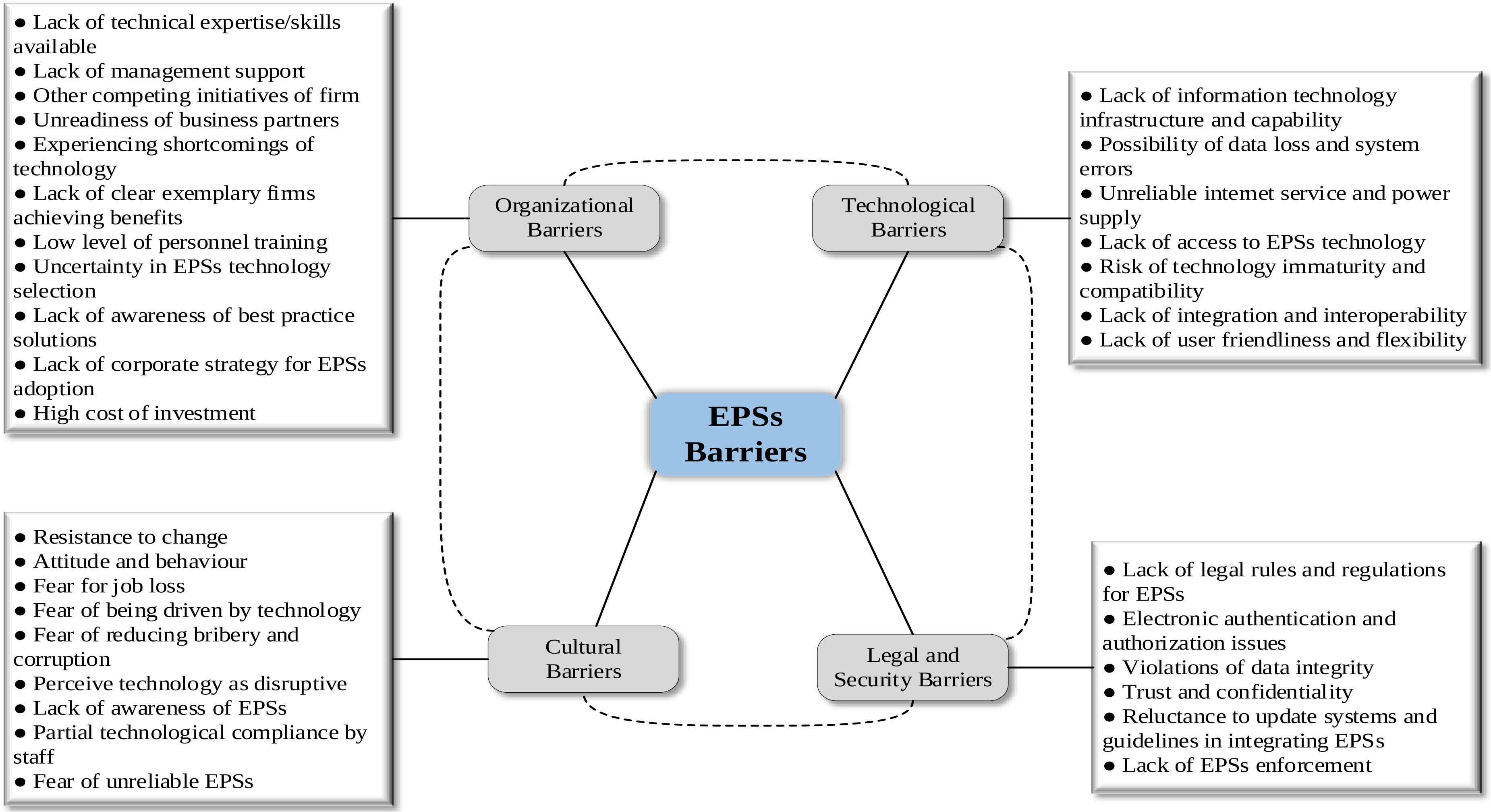

Fig. 5.1 Conceptual categorization of barriers to EPSs adoption in the construction industry

——— Categorized barrier ------------ Interrelationships between categorized barriers

5.2.1.1 Organizational Barriers

The organizational barrier category refers to characteristics of organizations deterring the adoption of EPSs. Organizational barriers are concerned with the obstacles creating difficulties for adopting EPSs technology in the organizational structure and processes (Altuwaijri and Khorsheed, 2012; Pan et al., 2020). From Fig. 5.1, 11 barriers including the high cost of investment, lack of technical expertise/skills available, lack of management support etc. were grouped into this category, making it the largest category regarding the number of barriers identified. This suggest that the structure, decisions and processes of the organization have significant impact on the effective adoption of EPSs.

From Table 5.1, specific barriers such as lack of technical expertise/skills available, high cost of investment and lack of clear exemplary firms achieving benefits within the organizational barriers category have been prevalent in literature over the years. For instance, Ozorhon et al. (2016) and Altuwaijri and Khorsheed (2012) emphasized that qualified personnel and knowledge are required for technological innovation to be adopted successively, hence the unavailability of experts within the organization leads to the organization’s decline to use EPSs. Kang et al. (2012) indicated that limited capital investments and financial resources of an organization has the propensity to negatively influence EPSs adoption. Moreover, the high implementation and maintenance cost associated with the technology has discouraged its uptake and continuous usage in the construction industry due to the limited financial resources of construction organizations (Ozorhon et al., 2016). Other frequent barriers within this category are lack of management support and unreadiness of business partners. The lack of strong leadership and continuous commitment towards EPSs adoption as highlighted by Altuwaijri and Khorsheed (2012), makes it difficult for EPSs to be implemented. Because the decisions taken by the top management guides the activities of the organization to perform its responsibilities and operations.

5.2.1.2 Technological Barriers

The technological barrier category focuses on barriers arising from the requirements or management needed for EPSs technology. Seven barriers were identified to fall under this category (Fig. 5.1). Barriers such as lack of IT infrastructure and capability, lack of integration and interoperability, and risk of technology immaturity and compatibility were mostly identified by studies in this category. The technical requirements of EPSs present hindrances to the adoption of the technology. While lack of IT infrastructure and capability was identified as a major barrier by Ibem and Laryea (2015), it was also the barrier highly identified by previous studies in this category. Lack of IT infrastructure and capability has been identified under this category over the years to hinder EPSs use in the construction industry. Studies from Wimalesena and Gunatilake (2018), Altuwaijri and Khorsheed (2012) and Abu-ElSamen et al. (2010) observed that poor IT infrastructure of the construction organization prevents it from adopting EPS. Other specific barriers such as risk of technology immaturity and compatibility have also been prominent within the technological category over the years. This suggests that practitioners within the construction industry are challenged with the suitability of the technology available with respect to the rapid advancement of digital tools in the construction industry.

5.2.1.3 Legal and Security Barriers

With the legal and security barriers category, it shows how the legal and security framework poses a challenge for the adoption of EPSs. Since procurement of contracts are legally grounded (Das et al., 2020; Eadie et al., 2010a), the absence of laws and rules guiding EPSs usage deters construction stakeholders from adopting it. Similarly, the inadequacy of security mechanisms surrounding EPSs presents major hindrances to its implementation (Eadie et al., 2010b). The level of legal backing for EPSs ensures that security mechanisms are properly implemented. From Fig. 5.1 barriers such as lack of legal rules and regulations for EPSs, electronic authentication and authorization issues, and lack of trust and confidentiality were grouped in this category. The high level of privacy and confidentiality needed for corporate documents and transactions presents challenges when adopting EPSs technology. Two specific barriers mostly identified throughout the years are lack of trust and confidentiality and lack of legal rules and regulations for EPSs. Studies by Ibem and Laryea (2015) and Kim et al. (2016) emphasized that the confidentiality of the EPSs process for document exchange was a key barrier challenging the uptake of the technology among construction stakeholders. Coupled with the absence of a legal regulatory framework for EPSs processes (Adriaanse et al., 2010; Kim et al. 2016), there is a general avoidance of EPSs adoption in the construction industry. Since, the construction industry is prone to disputes, the lack of security and legal support concerning the EPSs process makes construction stakeholders reluctant in its adoption.

5.2.1.4 Cultural Barriers

The cultural barriers category refers to the dynamics of human conduct and perceptions from the individual, corporate and industry levels in the construction industry (Hwang et al., 2020). From Fig. 5.1, a total of 10 barriers were grouped including resistance to change, attitude, behaviour and culture, fear for job loss, fear of being driven by technology etc. These cultural barriers focus on beliefs, emotions and perceptions impeding the adoption of EPSs in the construction industry (Altuwaijri and Khorsheed, 2012). These beliefs and perceptions involve undefined insights based on some experiences varying from person to person (Alomari et al., 2018), which in turn, creates complex challenges for EPSs adoption. For instance, the resistance to change barrier was one of the most identified barriers by the previous studies from Table 5.2 to EPSs uptake. This barrier could be initiated from the individual/corporate/industry level towards EPSs usage (Lines et al, 2017). For example, from the individual level, the resistance to change barrier could be cognitive which looks at interactions of self-interest and change or it could be affective which refers to emotional and psychological reaction to change (Lines et al, 2017). From Table 5.2, resistance to change and attitude and behaviours were identified as frequent barriers to EPSs in literature. For instance, Sheriff et al. (2012) indicated that resistance to change cannot be avoided but should be rather mitigated, since people have a natural repulsion towards changing their ways of doing tasks. Dossick and Sakagami (2008) and Kang et al. (2012) acknowledged that attitudinal and behavioural actions of persons mainly hinder EPSs adoption when compared to the technological challenges.

5.2.2 Knowledge Gaps

The review of literature on the barriers to EPSs revealed that there are knowledge gaps in this domain of EPSs research. This study observed that while several studies have identified individual issues hindering EPSs adoption on projects, knowledge on the clustering effect of these barrier groupings is yet to be known. More importantly, the complex influence patterns of the barrier groups on hindering EPSs implementation on projects is lacking in literature. This presents a challenge for the implementation of EPSs since the ability to predict these barriers and their synergistic influences based on prevailing project environments is scarce in EPSs literature. This is essential for effective planning of mitigation efforts in EPSs adoption and would enable researchers to understand the influence patterns of barriers on EPSs implementation in the construction industry.

5.3 STRATEGIES PROMOTING EPSs IMPLEMENTATION[6]

This section discusses the various strategies employed by key construction stakeholders such as governments, industry councils, regulatory agencies and organizations to help promote EPSs uptake and mitigate the barriers to their adoption. EPSs are gaining attention at the continental and national levels, hence initiatives and measures have been adopted to facilitate their adoption. A review of literature was conducted using the systematic literature review technique to identify the strategies promoting EPSs for widespread adoption.

A comprehensive search process including journals from Wing (1997), search engines – Scopus and snowballing technique was employed to identify relevant papers for the review (Tranfield et al., 2003; McNamara and Sepasgozar, 2021). The keywords used for the search included electronic procurement, e-procurement, strategies, promotion, measures and construction. The titles, abstract and full text of the papers were screened, and irrelevant papers were excluded. After the screening, a review of the relevant papers was conducted. A total of 22 strategies were identified from 41 relevant papers. Table 5.3 provides the identified strategies and their corresponding codes to be used in Table 5.4. Table 5.4 presents a summary of the strategies with their respective reference sources. The discussions of the top strategies are discussed subsequently as follows.

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[6] This section is published in:
Yu, A. T. W., Yevu, S. K., and Nani, G. (2020). Towards an integration framework for promoting electronic procurement and sustainable procurement in the construction industry: A systematic literature review. *Journal of Cleaner Production*, *250*, 119493.

Table 5.3 Strategies promoting EPSs implementation in the construction industry

Code	Strategies promoting EPSs
PSt1	Align EPSs to organisation’s strategy and procurement procedures.
PSt2	Incentives and reward schemes for EPSs adoption on projects
PSt3	Competent institutional framework for effective EPSs implementation
PSt4	Enable collaborative environment among organisations and partners
PSt5	EPSs related educational and training programs for client organisations, property developers, contractors, suppliers and policy makers.
PSt6	An active and strengthened research and development for EPSs implementation
PSt7	Pilot implementation projects for contextual learning experience and knowledge sharing
PSt8	Availability of best practice frameworks for EPSs
PSt9	Proactive change-management methods and innovation culture
PSt10	Organisational leadership buy-in and commitment strategy for EPSs implementation
PSt11	Publicity through media (e.g. internet, print media, radio, television)
PSt12	Availability of quantifiable evidence of EPSs benefits (e.g. market leaders)
PSt13	Ensure standardisation and simplification of process across systems
PSt14	Availability of competent local promotion and implementation teams
PSt15	Develop awareness programmes through workshops, seminars and conferences
PSt16	Promotion programmes linked to continuous professional development
PSt17	Mandatory EPSs policies and regulations
PSt18	Lower and subsidised cost of EPSs technology
PSt19	Incorporating cultural dynamics into technology development
PSt20	Framework for developing capacity of organisations at local levels
PSt21	Availability of financial support schemes for EPSs technology investment
PSt22	Availability of technological support systems after EPSs is implemented

Note: PSt = Promotion Strategy

Table 5.4 Summary of identified EPSs strategies with reference sources

Reference	EPSs Strategies																					
	PSt1	PSt2	PSt3	PSt4	PSt5	PSt6	PSt7	PSt8	PSt9	PSt10	PSt11	PSt12	PSt13	PSt14	PSt15	PSt16	PSt17	PSt18	PSt19	PSt20	PSt21	PSt22
Pala et al. (2016)				X				X				X										
Jacobsson and Linderoth (2010)																	X					
Jacobsson et al. (2017)				X													X					
Hua (2007)				X																		
Dossick and Sakagami (2008)				X	X			X			X									X		
Adriaanse et al. (2010)	X	X	X					X						X							X	
Jaafar et al. (2007a)				X	X	X																
Peansupap and Walker (2006)					X		X	X														
Ruikar et al. (2005)					X				X	X		X										
Sarshar and Isikdag (2004)					X	X		X														
Kim et al. (2016)					X				X	X	X				X							
Kang et al. (2012)									X	X												
Lines et al. (2017)					X				X			X										X
Ozorhon et al. (2016)		X		X	X		X			X											X	
Jaafar et al. (2007b)					X	X					X					X				X		
Wang et al. (2007)				X									X	X			X					
Altuwaijri and Khorsheed (2012)				X	X					X												
Liao et al. (2002)	X				X																	
Anumba and Ruikar (2002)	X					X						X		X			X					
Alshawi and Ingirige (2003)		X							X	X								X				
Nitithamyong and Skibniewski (2004)				X																		

Table 5.4 Summary of identified EPSs strategies with reference sources (*continued*)

Papers	EPSs Strategies																					
	PSt1	PSt2	PSt3	PSt4	PSt5	PSt6	PSt7	PSt8	PSt9	PSt10	PSt11	PSt12	PSt13	PSt14	PSt15	PSt16	PSt17	PSt18	PSt19	PSt20	PSt21	PSt22
Ruikar et al. (2006)								X	X	X		X										
Aibinu and Al-Lawati (2010)							X									X	X					X
Eadie et al. (2011)												X										
Wimalasena and Gunatilake (2018)		X		X					X	X					X		X				X	
Loforte Robeiro and Love (2003)								X										X				
Love et al. (2001)					X				X	X												
Ibem et al. (2016)												X				X		X				
Rankin et al. (2006)															X		X	X				
Ibem and Laryea (2015)			X	X	X	X					X			X		X			X			
Oyediran and Akintola (2011)																X						
Lou and Alshawi (2009)	X								X			X										
Zou and Seo (2006)		X			X		X			X			X		X		X	X			X	
Reddick (2004)			X							X										X		
Leipold et al. (2004)					X				X	X	X			X						X		X
El-Diraby (2013)						X	X	X							X							
Al Yahya et al. (2018)				X																		
Nawi et al. (2017)																				X		
Naoum and Egbu (2016)									X				X									
Costa and Tavares (2014)				X																		X
Arslan et al. (2006)	X																X	X				
Total	5	5	3	13	15	6	5	8	11	12	5	8	3	5	5	5	9	6	1	5	4	4

To focus on the top EPSs strategies frequently identified from literature (Table 5.4), '*EPSs-related educational and training programmes for stakeholders'* was the most popular strategy in these studies. Ozorhon et al. (2016) and Dossick and Sakagami (2008) highlighted the influence of training programmes on facilitating the web-based project management tools among organisations. Such training provides motivations for construction stakeholders through acquiring technological skills in adopting EPSs (Kim et al., 2016; Altuwaijri and Khorsheed, 2012). Zou and Seo (2006) indicated that a continuous learning approach should be employed for educational training of construction stakeholders to ensure wider adoption of EPSs in the construction industry.

The strategy to *'enable collaborative environment among organisations and partners'* accentuates the need for good relationships among construction partners. Pala et al. (2016) indicated that for EPSs to be implemented successfully, strategic collaborative efforts from clients, consultants and contractors/suppliers are required before the implementation of EPSs innovation Hence, such collaborative environments produce fertile fields since internal business processes will be aligned strategically among partners for widespread adoption in the construction industry (Nitithamyong and Skibniewski, 2004; Pala et al., 2016).

Further, Jacobsson et al. (2017) revealed that the adoption of information technologies such as EPSs in the construction industry is hinged to the interplay among mutually reinforcing environments in the industry. Therefore, fostering an ecosystem of collaboration early before the EPSs uptake facilitates a broader implementation. Another strategy which has gained attention in literature is *'organisational leadership buy-in and commitment strategy for EPSs implementation'*. Ruikar et al. (2005) indicated the criticality of top management buy-in to the attainment of widespread adoption of EPSs in the construction industry. In support of this findings, Kim et al. (2016) realized that since organisational leadership provides the funding and resources for technological adoption, active engagement of leadership of various organisations ensures the commitment of business strategies towards adopting EPSs.

The *'proactive change-management methods and innovation culture'* strategy describes an organisational culture that integrates innovation encouragement and cooperativeness (Kang et al., 2012). The management of change should be proactive and directed towards the hard and soft issues of people, process and technology (Wimalasena and Gunatilake, 2018; McNamara and Sepasgozar, 2021; Lou and Alshawi, 2009). Ruikar et al. (2005) indicated that the change strategy promoting EPSs adoption should take a gradual approach since the construction industry is conservative to change. The change strategy should be comprehensive towards the complexities of behavioural dimensions and isomorphic forces.

The strategy '*mandatory EPSs policies and regulations'* addresses initiatives from government and statutory bodies in promoting EPSs implementation on projects. Aibinu and Al-Lawati (2010) discovered that the confidence in adopting EPSs by suppliers and other partners increased when EPSs was made mandatory for public agency's procurement activities. Wimalasena and Gunatilake (2018) indicated that government plays an influential role in formulating and implementing legal rules and regulations which facilitates widespread adoption of EPSs on construction projects in a country. These policies could also be made compulsory at the organisational level (Jacobsson et al., 2017). This action creates a compulsive force for the uptake of EPSs in the construction industry.

The *'availability of quantifiable evidence of EPSs benefits'* strategy provides motivations for the uptake of EPSs. The availability of information on EPSs benefits realized from early adopters could encourage other stakeholders to adopt EPSs (Alshawi and Ingirige, 2003; Adriaanse et al., 2010). This also allows for maximisation of benefits to be measured (Dossick and Sakagami, 2008; Ibem et al., 2016). Pala et al. (2016) emphasized that showing quantifiable proofs of benefits to construction stakeholders using real end-to-end cases accelerates the technology adoption. Considering the '*availability of best practice frameworks for EPSs'* strategy, Adriaanse et al. (2010) showed that guided mechanisms foster inter-organisational usage of information technologies. Sarshar and Isikdag (2004) presented the importance of consolidating the learning experiences from other adopting countries to facilitate EPSs initiatives in other countries.

5.3.1 Knowledge Gaps

Though these strategies have been suggested in literature to promote EPSs in the construction industry, knowledge about their influences in promoting EPSs adoption are yet to be established in EPSs literature. Additionally, since these strategies are not applied as stand-alone in project environments, the clustering and synergistic impacts of these strategies are needed to the inform decision-making process on effective ways of applying the strategies. This study contributes to addressing this knowledge gap by examining the impact of these strategies in promoting EPSs adoption in construction projects.

5.4 COMPREHENSIVE LIST OF BARRIERS AND STRATEGIES FOR THE SURVEY

In generating the comprehensive list of barriers and strategies factors, barriers/strategies having high similarity in attributes and focus were synthesized, and priority was given to the barriers/strategies mostly identified by previous studies. This approach ensures that the generated list is more applicable, concise and would allow respondents to respond easily (Chan et al., 2018; Rowlinson, 1988). To this end, the barriers and strategies list are presented in Table 5.5 and Table 5.6, respectively.

Table 5.5 List of barriers to EPSs adoption

Code	Barriers to EPSs	Selected reference(s)
B01	Perceive technology as disruptive	[2]; [5]; [6]
B02	Resistance to change attitude	[3]; [4]; [6]; [7]; [8]
B03	Electronic authentication and authorization issues	[2]; [4]; [9]; [10]
B04	Unreliable internet service and power supply	[2]; [10]
B05	Violations of data integrity and possibility of data loss	[5]; [9]; [11]
B06	Lack of trust and confidentiality of the electronic system	[3]; [4]; [10]
B07	Lack of information technology (IT) infrastructure and capability	[1]; [2]; [8]
B08	Lack of legal rules and regulations for EPSs	[4]; [11]
B09	Lack of awareness and access to EPSs	[2]; [9]
B10	Lack of electronic contract enforcement	[4]; [9]
B11	Low level availability of technical expertise/skills	[1]; [12]
B12	Lack of user friendliness and flexibility of EPSs	[4]; [9]
B13	High cost of EPSs investment	[1]; [2]; [13]
B14	Fear for reducing bribery and procurement malpractices	[2]
B15	Fear for job loss (partial technological compliance by staff)	[2]; [14]
B16	Lack of demonstration of firms achieving benefits	[1]; [9]; [12]
B17	Insufficient management support for EPSs	[8]; [12]; [15]
B18	Unreadiness of business partners	[16]; [17]; [18]
B19	Uncertainty of EPSs maturity	[9]; [19]
B20	Other competing initiatives of firm and lack of corporate strategy	[20]
B21	Lack of incentives for EPSs adoption	[17]; [21]

Note: [1]= Khan et al. (2016); [2]= Ibem and Laryea (2017); [3]= Costa and Tavares (2013); [4]= Wimalasena and Gunatilake (2018); [5]=Sheriff et al. (2012); [6]= Liu et al. (2018); [7]= Pala et al. (2016); [8]= Altuwaijri and Khorsheed (2012); [9]= Eadie et al. (2011); [10]= Aibunu and Al-Lawati (2010); [11]= Ibem and Laryea (2015); [12]= Ozorhon et al. (2016); [13]= Tas et al. (2013); [14]= Lou and Alshawi (2009); [15]= Dossick and Sakagami (2008); [16]= Zunk et al. (2014); [17]= Wong and Zhang (2013); [18]= Kang et al. (2012); [19]= Kang et al. (2015); [20]= Zou and Seo (2006); [21]= Williams et al. (2007).

Table 5.6 List of strategies promoting EPSs implementation

Code	Strategies promoting EPSs	Selected reference(s)
S01	Align EPSs to organisation’s strategy and procurement procedures.	[7]; [5]
S02	Reward schemes for EPSs adoption on projects	[2]; [4]; [7]
S03	Competent institutional framework and local promotion teams for effective EPSs implementation	[7]; [8]

S04	Enable collaborative environment among organisations and partners	[1]; [2]; [3]; [4]; [6]; [9]; [17]
S05	EPSs related training programs for key stakeholders	[2]; [6]; [8]; [9]; [10]
S06	Active and strengthened research and development for EPSs implementation	[8]; [12]
S07	Pilot implementation projects for contextual learning and knowledge sharing	[2]; [12]; [13]
S08	Proactive change-management systems	[4]; [5]; [10]; [11]; [14]
S09	Organisational leadership buy-in and commitment strategy for EPSs	[2]; [4]; [9]; [10]; [14]
S10	Active publicity through media communications	[6]; [8]; [10]
S11	Availability of quantifiable evidence of EPSs benefits	[1]; [5]; [11]; [15]
S12	Ensure standardisation and simplification of process across systems	[16]
S13	Mandatory EPSs policies and regulations	[4]; [13]; [16]
S14	Availability of financial support schemes for EPSs investment	[2]; [4]; [7];

Note: [1]= Pala et al. (2016); [2]= Ozorhon et al. (2016); [3]= Costa and Tavares (2014); [4]= Wimalasena and Gunatilake (2018); [5]= Lou and Alshawi (2009); [6]= Dossick and Sakagami (2008); [7]= Adriaanse et al. (2010); [8]= Ibem and Laryea (2015); [9]= Altuwaijri and Khorsheed (2012); [10]= Kim et al. (2016); [11]= Lines et al. (2017); [12]= El-Diraby (2013); [13]= Aibinu and Al-Lawati (2010); [14]= Kang et al. (2012); [15]= Eadie et al. (2011) [16]= Wang et al. (2007); [17]= Jacobsson et al. (2017).

5.5 CHAPTER SUMMARY

This chapter reviewed and discussed literature on the barriers to EPSs uptake. Subsequently, the barriers identified were categorized in this chapter. Further, the strategies promoting EPSs in construction projects were identified from literature and discussed. This review provides the foundation for empirical investigation on the barriers and strategies needed for understanding EPSs implementation.

CHAPTER 6 ANALYSIS AND RESULTS – MODEL FOR EPSs DRIVER BENEFITS AND QUANTITATIVE EVALUATION[7]

6.1 INTRODUCTION

Chapter 6 reports on the influences of benefit drivers in EPSs adoption and the prioritized benefits of EPSs for quantitative assessment. While the previous chapter (Chapter 4) focused on the literature review of EPSs benefit drivers, the present chapter has objectives of identifying the major benefit drivers, revealing the underlying clusters, modelling the influences of clustered benefit drivers and determining the priorities for benefits quantitative evaluation selection. To attain the goal of this chapter, the 26 benefit drivers as indicated in Table 4.5 from the literature review, were employed in a questionnaire survey involving 121 respondents for significance assessment using a five-point rating scale. The background profiles of respondents are presented in Table 2.5. The data collected were thoroughly analyzed using SPSS 23.0 statistical package for mean and descriptive analysis and uncovering the underlying grouping dimensions of benefits drivers. Further, the influence model development for benefit drivers was derived via the application of the fuzzy synthetic evaluation (FSE) method. For priorities of EPSs benefits regarding quantitative assessment, the grouped benefits obtained formed the basis for the AHP priority weight analysis. The results of the data analysis are thoroughly discussed in this chapter.

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6.2 DATA ANALYSIS RESULTS AND DISCUSSIONS

Preliminary test for internal consistency of the data collected using the Cronbach's alpha method, obtained an overall coefficient $\propto$ value of 0.806 for the 26 DFs, indicating that the dataset has high consistency and reliability (Field, 2013). Further, data normality check was conducted using the Shapiro-Wilk test (SW) and all the factors showed *p-values <0.05*. This suggests that the dataset is not normally distributed (Royston, 1992).

6.2.1 Main Benefit Drivers for EPSs Adoption in Projects

The summary of the mean analysis and ranking results is shown in Table 6.1. The mean scores which indicate the influence of DFs, ranged between 3.01 and 4.69. The DFs with normalized values not less than 0.50 were identified as critical DFs for the application of EPSs.

Table 6.1 shows that 19 out of the 26 DFs had normalized values above 0.50, and were henceforth deemed critical driving forces (CDFs). Overall, *'reduce cycle times for process and transaction'* (DF02) was ranked first with the highest mean score (mean = 4.69). This indicates that reducing the time or duration for procurement processes contrary to existing prolonged procurement timelines, is key in influencing the implementation of EPSs on projects, and concurs with Doloi (2014) that on-time delivery is a vital benefit desired by project professionals. Also, the study by Gardenal (2013) showed that 35% reduction in time was attainable in procurement processes with the use of EPSs. From the GCI context, Ottou et al. (2020) showed proposed timelines of 13-20 weeks for the procurement process, however, Anvuur et al. (2006) suggested that these timelines are usually prolonged in the conventional procurement process, and that could be the motivation for project professionals' high interest in EPSs uptake in the GCI. The second rank, *'reduce process, transaction and administrative* *cost'* (DF01) (mean = 4.60) lends support to previous studies such as Lenin (2011) that showed cost savings of US$ 19,167.15 by using EPSs in the bidding process. Further, the 10% reduction in cost of bidding documents as demonstrated by Santoso and Bourpanus (2019), suggest that when more cost savings from many bidding procurement processes are aggregated, the gains would be significant to the organization.

The DF17 *'improved audit trail and accountability'* (mean = 4.55) was ranked third, indicating a high driving influence within the Ghanaian construction context. With the increasing occurrence of project disputes, keeping an audit trail of system transactions enhances accountability on projects (Nitithamyong and Skibniewski, 2006). Remarkably, DF08 *'increase transparency, trust and reliability of the process'* (mean = 4.51) was highly rated a critical force for EPSs implementation, and supports Wimalasena and Gunatilake (2018) assertion that transparency is highly desired of the procurement process by project stakeholders to ensure reliability. Unexpectedly, *'promoting paperless environment'* (DF16) (mean = 4.48) was identified as a major driving force (5th rank) for EPSs although it was less recognized in previous studies. Enhancing environmental sustainability through reduced paperwork and travel itinerary contributes towards efficient use of resources on projects (Gardenal, 2013). Thus, project professionals in Ghana view digitization of procurement as an effort to attain sustainability targets at any stage of the project lifecycle. Although cost and time savings have been prominent DFs for EPSs implementation, the increasing recognition for a paperless environment among practitioners in GCI provides new insights about the growing impact of sustainability on project procurement and could be explored for sustainable procurement.

As shown in Table 6.1, The Kendall's *W* value for ranking the 26 DFs was 0.259 at a significance level of 0.000, indicating that there exists substantial degree of agreement on the ranking of DFs among all three respondent groups. From the Kruskal-Wallis test results, 18 DFs had no statistically significant difference (significance value > 0.05) while eight DFs had significant difference (significance value ≤ 0.05) in rankings among the respondent groups (see Table 6.1). The consultant and contractor groups had higher ranks for 'reduce cycle times for process and transaction', 'reduce process, transaction and administrative cost' and improved audit trail and accountability' respectively. Meanwhile, the regulatory authority group had lower ranking for these three forces, impling that consultants and contractors were driven by time, cost and accountability benefits of EPSs compared to regulatory practitioners. On the contrary, the regulatory practitioners had higher rankings for DF22 'enhance regulatory compliance on contracts' when compared to the consultant and contractor professionals.

Table 6.1 Summary of mean analysis for DFs regarding EPSs application

Code	All respondents				Consultant			Contractor			Regulatory Authority			Kruskal-Wallis
	Mean	SDv	Rank	Normalization[a]	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Test
DF02	4.69	0.62	1	1.00[b]	4.76	0.43	1	4.86	0.45	1	4.35	0.98	2	0.034[c]
DF01	4.60	0.63	2	0.95[b]	4.75	0.44	2	4.61	0.57	2	4.23	0.91	5	0.013[c]
DF17	4.55	0.66	3	0.91[b]	4.64	0.54	3	4.75	0.52	3	4.08	0.84	11	0.001[c]
DF08	4.51	0.62	4	0.89[b]	4.58	0.55	4	4.29	0.76	6	4.58	0.58	1	0.185
DF16	4.48	0.72	5	0.87[b]	4.52	0.70	5	4.61	0.63	4	4.23	0.82	5	0.141
DF14	4.31	0.70	6	0.77[b]	4.37	0.65	6	4.36	0.68	5	4.12	0.82	10	0.371
DF15	4.17	0.69	7	0.69[b]	4.18	0.60	7	4.14	0.76	8	4.15	0.83	9	0.973
DF24	4.13	0.72	8	0.67[b]	4.18	0.72	7	4.14	0.65	8	4.00	0.80	13	0.592
DF03	4.10	0.57	9	0.65[b]	4.10	0.50	10	4.18	0.48	7	4.00	0.80	13	0.607
DF05	4.08	0.73	10	0.64[b]	4.03	0.78	12	4.07	0.66	10	4.23	0.65	5	0.513
DF23	4.07	0.72	11	0.63[b]	4.13	0.65	9	3.71	0.66	19	4.27	0.83	3	0.008[c]
DF04	4.03	0.58	12	0.61[b]	4.04	0.56	11	3.96	0.58	13	4.08	0.63	11	0.747
DF25	4.03	0.72	13	0.61[b]	4.00	0.70	14	3.93	0.81	14	4.23	0.65	5	0.265
DF07	4.02	0.68	14	0.60[b]	4.00	0.60	14	4.07	0.66	11	4.00	0.89	13	0.857
DF19	3.99	0.69	15	0.58[b]	4.03	0.70	12	3.93	0.66	14	3.96	0.72	17	0.783
DF22	3.98	0.75	16	0.58[b]	3.97	0.76	16	3.75	0.75	18	4.27	0.67	3	0.039[c]
DF12	3.93	0.72	17	0.55[b]	3.91	0.75	18	3.93	0.54	14	4.00	0.80	13	0.911
DF06	3.91	0.65	18	0.53[b]	3.91	0.65	18	4.00	0.47	12	3.81	0.80	22	0.674
DF18	3.87	0.71	19	0.51[b]	3.97	0.72	16	3.79	0.57	17	3.69	0.79	25	0.274
DF13	3.63	0.73	20	0.37	3.54	0.70	21	3.68	0.67	20	3.81	0.85	22	0.224
DF20	3.59	0.74	21	0.34	3.46	0.64	23	3.54	0.64	21	3.96	0.96	17	0.008[c]
DF21	3.59	0.76	22	0.34	3.48	0.70	24	3.54	0.58	21	3.92	0.98	19	0.091
DF09	3.57	0.76	23	0.33	3.58	0.80	20	3.29	0.60	25	3.85	0.73	21	0.021[c]
DF10	3.56	0.75	24	0.33	3.54	0.78	21	3.46	0.51	23	3.73	0.87	24	0.395
DF26	3.50	0.68	25	0.29	3.36	0.57	25	3.46	0.58	23	3.92	0.89	19	0.006[c]
DF11	3.01	0.77	26	0.00	2.94	0.74	26	3.00	0.67	26	3.19	0.94	26	0.479

Note: SDv = Standard Deviation;

[a]Normalization = (Mean – Minimum Mean) / (Maximum Mean – Minimum Mean);

[b]The normalized value indicates that the driving force has significant influence (normalized value ≥ 0.50);

[c]The Kruskall-Willis test value is significant at the ≤ 0.05 significance level. The Shapiro-Wilk test value for all 26 driving factors were ≤ 0.05 significant level. The Kendall's *W* for ranking the 26 driving factors was 0.259 with significance level of 0.000.

6.2.1.1 Global perspectives: Ghana, Hong Kong and selected developed economies

An additional survey was conducted to compare the survey results of this study to the perspectives of professionals in developed economies such as Hong Kong, the United States, the United Kingdom and Australia. Table 6.2 presents the mean comparison results of top 10 EPSs benefit drivers between Ghana, Hong Kong and selected developed economies (i.e. the US, the UK and Australia). Such comparisons are needed to strengthen EPSs implementation knowledge at the global level.

The results in Table 6.2 indicate that while reduce cycle times for process and transaction was the highest ranked driver in the GCI, it was ranked tenth and fourth in Hong Kong and the selected developed countries respectively. This finding is reasonable as procurement processes are typically prolonged in Ghana which may not be the case in Hong Kong and the selected developed economies, as their procurement processes might have been improved. Nevertheless, Hong Kong ranked promoting paperless environment as the highest driver while the selected developed countries identified improved audit trail and accountability as the highest driver. It is interesting that EPSs benefit drivers that appeared in the top five across Ghana, Hong Kong and the selected developed economies were improved audit trail and accountability and promoting paperless environment. Conspicuously, environmental sustainability concerns have become a major driver for EPSs implementation across these regions globally. Although, reduce process, transaction and administrative cost were highly ranked in Ghana and the selected developed economies, it is rather close to appearing in the top five benefit drivers of EPSs in Hong Kong. One possible explanation could be Hong Kong's overriding emphasis to improve environmental sustainability in the construction sector, hence, the promotion of paperless environment was considered the main benefit driver.

Interestingly, while EPSs ability to reduce bid collusion and corrupt practices was significantly considered as a benefit driver in Ghana, Hong Kong and the selected developed countries considered it not significant as it was ranked low. This suggests that although EPSs may have benefits of reducing procurement malpractices, its benefits are multidimensional to the construction industry.

Table 6.2 Comparison of top 10 EPSs benefit drivers between Ghana, Hong Kong and selected developed economies.

EPSs Benefit Drivers	Ghana		Hong Kong		Selected Developed Economies[a]	
	Mean	Rank	Mean	Rank	Mean	Rank
DF02- Reduce cycle times for process and transaction	4.69	1[b]	4.06	10	4.43	4[b]
DF01 - Reduce process, transaction and administrative cost	4.60	2[b]	4.12	7	4.51	2[b]
DF17 - Improved audit trail and accountability	4.55	3[b]	4.47	2[b]	4.63	1[b]
DF08 - Increase transparency, trust and reliability of the process	4.51	4[b]	4.29	4[b]	4.17	8
DF16 - Promoting paperless environment	4.48	5[b]	4.71	1[b]	4.43	5[b]
DF14 - Effective monitoring of process (real time)	4.31	6	3.71	15	4.09	11
DF15 - Platform for collaboration and added value services	4.17	7	3.65	17	3.94	15
DF24 - Reduce bid collusion and corrupt practices	4.13	8	3.65	16	3.46	20
DF03 - Improve efficiency and effectiveness in the process	4.10	9	4.41	3[b]	4.46	3[b]
DF05 - Ease of access to information and management of project data	4.08	10	4.18	5[b]	4.09	10

Note: [a] = United States, United Kingdom and Australia.
[b] = EPSs benefit drivers appearing in top five ranks of the selected countries/territories.

6.2.2 Factor Analysis Results

To classify the numerous CDFs identified for underlying dimensions, FA was employed on the 19 CDFs identified in Ghana. The KMO value of 0.632 obtained means that the value is acceptable since it is higher than 0.50 (Hair et al., 2009). The Bartlett's test value of 563.60 with 0.000 level of significance suggest that the correlation matrix is not an identity matrix (Pallant, 2011). Thus, the two tests indicate the dataset is suitable for FA. Consequently, the use of principal component analysis and varimax rotation extracted six underlying components with eigenvalues above one. This means that these six underlying components significantly contribute to understanding the DFs phenomenon. The six underlying components accounted for 60% of variance and hence satisfies > 50% variance threshold for adequate data representation (Field, 2013). As shown in Table 6.3, the components are labelled: integrity and environment-related forces, process optimization-related forces, fairness and conformance-related forces, information integration-related forces, client-related forces and smart resource system-related forces.

The six groupings (hereafter called principal driving forces, PDFs) identified, cover diverse aspects concerning construction project goals, demands and desired benefits professionals in the GCI expect. These groupings support partial findings from past studies that identified individual drivers such as transparent processes, cost reduction and improved monitoring as influential issues in EPSs implementation in the GCI (Owusu, 2015). However, since these DFs do not act alone, this study's groupings provide a more effective frame in understanding the behavior of the numerous DFs in the Ghanaian context. The importance of the classification is twofold; first, the PDFs serve as input variables for evaluating the influence level towards encouraging EPSs, and second, the PDFs provide a managerial framework for promoting EPSs by reducing cognitive complexity when managing numerous DFs. In using the PDFs, questions involving a specific PDF's contribution of influence and the total influence level of PDFs for EPSs implementation are assessed.

Table 6.3 Results of FA for grouping DFs for EPSs

Code	Driving forces for EPSs adoption	Components					
		1	2	3	4	5	6
Component 1: Integrity and environment-related forces (u_1)							
DF14	Effective monitoring of process (real time), u_{11}	0.647	-	-	-	-	-
DF16	Promoting paperless environment, u_{12}	0.714	-	-	-	-	-
DF17	Improved audit trail and accountability, u_{13}	0.694	-	-	-	-	-
DF24	Reduce bid collusion and corrupt practices, u_{14}	0.604	-	-	-	-	-
Component 2: Process optimization-related forces (u_2)							
DF01	Reduce process, transaction and administrative cost, u_{21}	-	0.759	-	-	-	-
DF02	Reduce cycle times for process and transaction, u_{22}	-	0.787	-	-	-	-
DF03	Improve efficiency and effectiveness in the process, u_{23}	-	0.540	-	-	-	-
DF06	Improve response, accuracy and flexibility of process, u_{24}	-	0.651	-	-	-	-
Component 3: Fairness and conformance-related forces (u_3)							
DF08	Increase transparency, trust and reliability of the process, u_{31}	-	-	0.692	-	-	-
DF22	Enhance regulatory compliance on contracts, u_{32}	-	-	0.707	-	-	-
DF23	Reduce transportation energy resources, u_{33}	-	-	0.514	-	-	-
Component 4: Information integration-related forces (u_4)							
DF05	Ease of access to information and management of project data, u_{41}	-	-	-	0.508	-	-
DF07	Improved communication with stakeholders, u_{42}	-	-	-	0.573	-	-
DF15	Platform for collaboration and added value services, u_{43}	-	-	-	0.707	-	-
DF19	Enhance inventory/archiving and document management, u_{44}	-	-	-	0.584	-	-
Component 5: Client-related forces (u_5)							
DF04	Fast exchange of information among stakeholders, u_{51}	-	-	-	-	0.817	-
DF18	Client satisfaction, u_{52}	-		-	-	0.610	-
Component 6: Smart resource system-related forces (u_6)							
DF12	Reduce staffing, u_{61}	-	-	-	-	-	0.572
DF25	Access to internet intelligent tools for decision-making, u_{62}	-	-	-	-	-	0.781
Eigenvalue		3.684	2.179	1.559	1.435	1.304	1.207
Variance (%)		19.389	11.469	8.206	7.537	6.862	6.353
Cumulative variance (%)		19.389	30.859	39.065	46.601	53.464	59.817

Note: Extraction method = principal component analysis; Rotation method = Varimax with Kaiser normalization; $U_{(1...n)}$ = DF identification number for FSE method.

6.3 FUZZY EVALUATION MODEL FOR INFLUENCES OF EPSs BENEFITS DRIVING FORCES

Since the respondents' evaluations are based on linguistic scales, the FSE technique develops a robust tool for handling such limitations and uncertainties prone to subjective evaluations (Zadeh, 1965). Also, the FSE technique aids in the modeling of multi-attributes towards the development of an overall output (Xu et al., 2010). Given that, the determination of influential levels of DFs for EPSs is fuzzy in nature and often draws on experts' subjective judgments, the FSE was deemed appropriate when handling such imprecise decision-making environments. The step-by-step process in developing the FSE model using the six groupings of DFs is presented as follows.

6.3.1 Developing a FSE for DFs influence level on EPSs implementation

In assessing the influence level of DFs on EPSs implementation, two different levels were established based on the PDF groups at the first level and the DFs within the PDFs at the second lower-level. The multi-level FSE was used to analyze lower to higher levels problems (Ameyaw and Chan, 2015). The step-by-step procedure for the research process with the fuzzy approach is presented as follows.

6.3.1.1 Establish the evaluation index system

An evaluation index system was established by defining the PDFs at the first level as $U = (u_1, u_2, u_3, \ldots, u_6)$ (Li et al., 2013). The CDFs from each PDF are expressed as second level index as follows:

$u_1 = \{u_{11}, u_{12}, u_{13}, u_{14}\}$;
$u_2 = \{u_{21}, u_{22}, u_{23}, u_{24}\}$;
$u_3 = \{u_{31}, u_{32}, u_{33}\}$;
$u_4 = \{u_{41}, u_{42}, u_{43}, u_{44}\}$;
$u_5 = \{u_{51}, u_{52}\}$;
$u_6 = \{u_{61}, u_{62}\}$

These index systems serve as input variables for FSE analysis. For instance, u_{12} is an input representing 'promoting paperless environment', classified under u_1 (integrity and environment-related forces).

6.3.1.2 Determining the weighting functions of the CDFs and PDFs

The relative significance of a variable as rated by the respondents is represented by the weighting function (w_i). The weighting function was derived through the normalized score of a CDF or PDF using:

$$w_i = \frac{M_i}{\sum_{i=1}^{5} M_i}, \ 0 < w_i < 1, \text{ and } \sum_{i=1}^{n} w_i = 1 \qquad (6.1)$$

where, w_i is the weighting function of a CDF/PDF i, and M_i represents the mean ratings of a particular CDF/PDF i from the survey. The set of weightings was computed as:

$$W_i = \{w_1, w_2, w_3 \dots w_n\} \quad (6.2)$$

6.3.1.3 Development of membership functions for each CDF and PDF

Membership functions (MF) for each CDF and PDF are calculated using fuzzy computations from the lower to higher levels (Ameyaw and Chan, 2015). The MF drew on the ratings provided by respondents based on a five-point rating scale (h_1 = strongly disagree (lowest) to h_5 = strongly agree (highest)) for levels of influence for the DFs. For a given CDF, the MF is computed using:

$$MF_{u_{in}} = \frac{x_{1u_{in}}}{h_1} + \frac{x_{2u_{in}}}{h_2} + \frac{x_{3u_{in}}}{h_3} + \frac{x_{4u_{in}}}{h_4} + \frac{x_{5u_{in}}}{h_5} \quad (6.3)$$

where $MF_{u_{in}}$ represents the membership function of particular DF u_{in}; u_{in} denotes the *n*th DF of a particular PDF (i.e. $u_1, u_2 \dots u_6$); $x_{g_{u_{in}}}$ is the percentage of responses received for each rating (g = 1, 2, 3, 4, 5) for a specific DF (u_{in}), hence showing the degree of MF. In FSE, the "+" represents a notation instead of an addition. The MF ranges between 0 and 1, and MF summation must equal 1:

$$\sum_{g=1}^{5} x_{g_{u_{in}}} = 1 \quad (6.4)$$

The weightings and MFs of all CDFs within a PDF group are subsequently computed and discussed.

6.3.1.4 Development of a multi-level FSE model

The evaluation of influences for various DFs presents a multi-level task when promoting EPSs implementation. The weightings and MFs of CDFs are initially established on a lower-level, followed by weightings and MFs assessments of PDFs on another level. The next level determines the overall driving influence level on EPSs project implementation. A fuzzy matrix D_i for each PDF using its MFs for CDFs within the group to determine the PDF's influence. The fuzzy evaluation matrix for MFs of all PDFs are derived as follows:

$$R_i = \begin{bmatrix} MF_{u_{i1}} \\ MF_{u_{i2}} \\ \vdots \\ MF_{u_{in}} \end{bmatrix} = \begin{bmatrix} x_{1_{u_{i1}}} & x_{2_{u_{i1}}} & x_{3_{u_{i1}}} & x_{4_{u_{i1}}} & x_{5_{u_{i1}}} \\ x_{1_{u_{i2}}} & x_{2_{u_{i2}}} & x_{3_{u_{i2}}} & x_{4_{u_{i2}}} & x_{5_{u_{i2}}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{1_{u_{in}}} & x_{2_{u_{in}}} & x_{3_{u_{in}}} & x_{4_{u_{in}}} & x_{6_{u_{in}}} \end{bmatrix} \tag{6.5}$$

where the matrix elements are given by $x_{g_{u_{in}}}$.

The fuzzy matrix, D_i, is derived using the weighting function (W_i= $\{w_{i1}, w_{i2}, w_{i3} \dots w_{in}\}$) of CDFs of PDF group *i* is expressed as:

$$D_i = W_i \bullet R_i = (w_{i1}, w_{i2}, w_{i3} \dots w_{in}) \bullet \begin{bmatrix} x_{1_{u_{i1}}} & x_{2_{u_{i1}}} & x_{3_{u_{i1}}} & x_{4_{u_{i1}}} & x_{5_{u_{i1}}} \\ x_{1_{u_{i2}}} & x_{2_{u_{i2}}} & x_{3_{u_{i2}}} & x_{4_{u_{i2}}} & x_{5_{u_{i2}}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{1_{u_{in}}} & x_{2_{u_{in}}} & x_{3_{u_{in}}} & x_{4_{u_{in}}} & x_{6_{u_{in}}} \end{bmatrix} \tag{6.6}$$

$$= (d_{i1}, d_{i2}, d_{i3}, \dots, d_{in})$$

where d_{in} represents the degree of membership for a rating score with respect to PDF *i* and "•" is the symbol for fuzzy composite operation. Afterwards, the matrices obtained, D_i(i =1, 2, 3, 4, 5, 6) creates a fuzzy matrix ($\bar{R}$) for evaluating the overall influence level of DFs for EPSs implementation:

$$\bar{R_\iota} = \begin{bmatrix} D_1 \\ D_2 \\ D_3 \\ D_4 \\ D_5 \\ D_6 \end{bmatrix} = \begin{bmatrix} d_{11} & d_{12} & d_{13} & d_{14} & d_{15} \\ d_{21} & d_{22} & d_{23} & d_{24} & d_{25} \\ d_{31} & d_{32} & d_{33} & d_{34} & d_{25} \\ d_{41} & d_{42} & d_{43} & d_{44} & d_{45} \\ d_{51} & d_{52} & d_{53} & d_{54} & d_{55} \\ d_{61} & d_{62} & d_{63} & d_{64} & d_{65} \end{bmatrix} \tag{6.7}$$

Note that D_1 to D_6 depict the six PDFs identified. Based on Eq. (6.6), normalization was conducted for $\overline{R_\iota}$ using the weightings ($W = \{w_1, w_2, w_3, w_4, w_5, w_6\}$) of the PDFs to generate the fuzzy evaluation matrix for overall influence computation:

$$\overline{D}_i = \overline{W}_i \bullet \overline{R}_i = (w_1, w_2, w_3, w_4, w_5, w_6) \times \begin{bmatrix} d_{11} & d_{12} & d_{13} & d_{14} & d_{15} \\ d_{21} & d_{22} & d_{23} & d_{24} & d_{25} \\ d_{31} & d_{32} & d_{33} & d_{34} & d_{25} \\ d_{41} & d_{42} & d_{43} & d_{44} & d_{45} \\ d_{51} & d_{52} & d_{53} & d_{54} & d_{55} \\ d_{61} & d_{62} & d_{63} & d_{64} & d_{65} \end{bmatrix} \quad (6.8)$$

$$= (L_1,\ L_2,\ L_3,\ L_4,\ \ L_5)$$

Where $\overline{D}_i = (L_1,\ L_2,\ L_3,\ L_4,\ \ L_5)$ is the fuzzy evaluation matrix or MF for the DF influence level for EPSs project implementation, and can be estimated with the grade alternatives $Q_n = (1, 2, 3, 4, 5)$ using Eq. (9):

$$\sum_{i=1}^{5} \overline{D_\iota} \times Q_n = (L_1,\ L_2,\ L_3,\ L_4,\ \ L_5) \times (1, 2, 3, 4, 5) \quad (6.9)$$

wherein the estimated influence value is $1 \leq IL \leq 5$, where IL denotes the overall influence level of main driving factors on EPSs adoption for projects.

6.3.2 Application of the fuzzy evaluation method

6.3.2.1 Determining the weightings of CDF and PDFs

The respective mean values from Table 6.1 were used to calculate the weightings for the second level (CDFs) and the first level (PDFs) as shown in Table 6.3. For example, the total mean value of PDF2: '*process optimization-related forces (u_2)*' comprising of four CDFs (see Table 6.3) is 17.31. Hence, the weighting function of each CDF, for instance, '*reduce cycle times for process and transaction, u_{22}*' is estimated using Eq. (6.1) as:

$$w_{u_{22}} = \frac{4.694}{4.603 + 4.694 + 4.099 + 3.909} = \frac{4.694}{17.31} = 0.271$$

Following the procedure above, all weightings of CDFs within a specific PDFs were calculated respectively. The sum of normalized weighting functions satisfies the criteria for Eq. (6.1) which is equal to 1 (Table 6.4). Further, using Eq. (6.1), the weightings for the PDF classifications ($u_1, u_2, \ldots, u_6$) were normalized in Table 6.4 as shown below:

$$w_{u_1} = \frac{17.47}{17.47 + 17.31 + 12.56 + 16.26 + 7.90 + 7.97} = \frac{17.47}{79.46} = 0.220$$

$$w_{u_2} = \frac{17.31}{17.47 + 17.31 + 12.56 + 16.26 + 7.90 + 7.97} = \frac{17.31}{79.46} = 0.218$$

$$w_{u_3} = \frac{12.56}{17.47 + 17.31 + 12.56 + 16.26 + 7.90 + 7.97} = \frac{12.56}{79.46} = 0.158$$

$$w_{u_4} = \frac{16.26}{17.47 + 17.31 + 12.56 + 16.26 + 7.90 + 7.97} = \frac{16.26}{79.46} = 0.205$$

$$w_{u_5} = \frac{7.90}{17.47 + 17.31 + 12.56 + 16.26 + 7.90 + 7.97} = \frac{7.90}{79.46} = 0.099$$

$$w_{u_6} = \frac{7.97}{17.47 + 17.31 + 12.56 + 16.26 + 7.90 + 7.97} = \frac{7.97}{79.46} = 0.100$$

Table 6.4 Weightings of CDFs and classified PDFs for EPSs implementation

CDFs and Classifications	Code	Mean (M_i)	Weightings of CDF (w_{in})	Total mean of PDF	Weightings of PDF (w_i)
Effective monitoring of process (real time)	DF14	4.314	0.247		
Promoting paperless environment	DF16	4.479	0.256		
Improved audit trail and accountability	DF17	4.546	0.260		
Reduce bid collusion and corrupt practices	DF24	4.132	0.237		
Integrity and environment-related forces (u_1)				17.47	0.220
Reduce process, transaction and administrative cost	DF01	4.603	0.266		
Reduce cycle times for process and transaction	DF02	4.694	0.271		
Improve efficiency and effectiveness in the process	DF03	4.099	0.237		
Improve response, accuracy and flexibility of process	DF06	3.909	0.226		
Process optimization-related forces (u_2)				17.31	0.218
Increase transparency, trust and reliability of the process	DF08	4.512	0.359		
Enhance regulatory compliance on contracts	DF22	3.984	0.317		
Reduce transportation energy resources	DF23	4.066	0.324		
Fairness and conformance-related forces (u_3)				12.56	0.158
Ease of access to information and management of project data	DF05	4.083	0.251		
Improved communication with stakeholders	DF07	4.017	0.247		
Platform for collaboration and added value services	DF15	4.165	0.256		
Enhance inventory/archiving and document management	DF19	3.992	0.246		
Information integration-related forces (u_4)				16.26	0.205
Fast exchange of information among stakeholders	DF04	4.033	0.510		
Client satisfaction	DF18	3.868	0.490		
Client-related forces (u_5)				7.90	0.099
Reduce staffing	DF12	3.9339	0.494		
Access to internet intelligent tools for decision-making	DF25	4.0331	0.506		
Smart resource system-related forces (u_6)				7.97	0.100
Total mean and weighting values				79.46	1.000

6.3.2.2 Establishing the MF for CDFs and PDFs

The MF for a CDF from the results is attained drawing on Eq. (6.3). For instance, using the survey results for '*promoting paperless environment (u_{12})*' showed the percentage of respondents' ratings as follows: 0% (Strongly disagree); 0% (Disagree); 13.22% (Neutral); 25.62% (Agree); and 61.16% (Strongly agree).

$$MF_{u_{12}} = \frac{0.00}{Strongly\ disagree} + \frac{0.00}{Disagree} + \frac{0.13}{Neutral} + \frac{0.26}{Agree} + \frac{0.61}{Strongly\ agree}$$

Therefore, the MF for CDF (u_{12}) is expressed as: (0.00, 0.00, 0.13, 0.42, 0.45). Using Eq. (6.3), the MFs for the remaining 18 CDFs were computed respectively.

6.3.2.3 Determining the influence level of each PDF

To determine the MFs for each PDF, a fuzzy matrix was initially derived using the results from Eq. (6.3) as shown in Table 6.4. For example, the fuzzy matrix of MFs for a PDF group (*integrity and environment-related forces*, u_1) is expressed using Eq. (6.5) as:

$$R_{u_1} = \begin{bmatrix} MF_{u_{11}} \\ MF_{u_{12}} \\ MF_{u_{13}} \\ MF_{u_{14}} \end{bmatrix} = \begin{bmatrix} 0.00 & 0.00 & 0.13 & 0.42 & 0.45 \\ 0.00 & 0.00 & 0.13 & 0.26 & 0.61 \\ 0.00 & 0.01 & 0.07 & 0.30 & 0.63 \\ 0.00 & 0.00 & 0.30 & 0.47 & 0.33 \end{bmatrix}$$

From the results in Eq. (6.5), the matrix is normalized based on the weighting functions of CDFs within the PDF group (u_1) using Eq. (6.6):

$$D_{u_1} = W_{u_1} \bullet R_{u_1} = (0.247, 0.256, 0.260, 0.237) \times \begin{bmatrix} 0.00 & 0.00 & 0.13 & 0.42 & 0.45 \\ 0.00 & 0.00 & 0.13 & 0.26 & 0.61 \\ 0.00 & 0.01 & 0.07 & 0.30 & 0.63 \\ 0.00 & 0.00 & 0.30 & 0.47 & 0.33 \end{bmatrix}$$
$$= (0.00, 0.00, 0.13, 0.36, 0.51)$$

The fuzzy evaluation matrix for the remaining PDFs are calculated following the same procedure. Using Eq. (6.9), the influence levels of various PDFs are determined (see Table 6.5) as expressed below:

$$IL_{u_1} = [(0.00 \times 1) + (0.00 \times 2) + (0.013 \times 3) + (0.36 \times 4) + (0.51 \times 5)] = 4.37$$

Similarly, $IL_{u_2} = (0.00, 0.01, 0.09, 0.43, 0.47) \times (1, 2, 3, 4, 5) = 4.35$

$$IL_{u_3} = (0.00, 0.00, 0.19, 0.42, 0.39) \times (1, 2, 3, 4, 5) = 4.20$$

$$IL_{u_4} = (0.00, 0.00, 0.19, 0.54, 0.27) \times (1, 2, 3, 4, 5) = 4.07$$

$$IL_{u_5} = (0.00, 0.01, 0.21, 0.60, 0.18) \times (1, 2, 3, 4, 5) = 3.95$$

$$IL_{u_6} = (0.00, 0.01, 0.24, 0.51, 0.24) \times (1, 2, 3, 4, 5) = 3.98$$

Table 6.5 Membership functions for CDFs and PDFs for EPSs implementation

CDFs and PDFs Classification	Code	Weightings for CDFs	MF for CDFs (Level-1)	MF for PDFs (Level-2)
Integrity and environment-related forces (u_1)				
	DF14	0.247	(0.00, 0.00, 0.13, 0.42, 0.45)	
	DF16	0.256	(0.00, 0.00, 0.13, 0.26, 0.61)	(0.00, 0.00, 0.13, 0.36, 0.51)
	DF17	0.260	(0.00, 0.01, 0.07, 0.30, 0.63)	
	DF24	0.237	(0.00, 0.00, 0.20, 0.47, 0.33)	
Process optimization-related forces (u_2)				
	DF01	0.266	(0.00, 0.02, 0.03, 0.30, 0.66)	(0.00, 0.01, 0.09, 0.43, 0.47)
	DF02	0.271	(0.00, 0.02, 0.03, 0.20, 0.76)	
	DF03	0.237	(0.00, 0.00, 0.12, 0.67, 0.22)	
	DF06	0.226	(0.00, 0.02, 0.21, 0.62, 0.15)	
Fairness and conformance-related forces (u_3)				
	DF08	0.359	(0.00, 0.00, 0.07, 0.36, 0.58)	(0.00, 0.00, 0.19, 0.42, 0.39)
	DF22	0.317	(0.00, 0.00, 0.29, 0.44, 0.27)	
	DF23	0.324	(0.00, 0.00, 0.22, 0.49, 0.29)	
Information integration-related forces (u_4)				
	DF05	0.251	(0.00, 0.00, 0.22, 0.47, 0.31)	(0.00, 0.00, 0.19, 0.54, 0.27)
	DF07	0.247	(0.01, 0.01, 0.15, 0.63, 0.21)	
	DF15	0.256	(0.00, 0.01, 0.14, 0.53, 0.32)	
	DF19	0.246	(0.00, 0.00, 0.24, 0.53, 0.23)	
Client-related forces (u_5)				
	DF04	0.510	(0.00, 0.00, 0.15, 0.67, 0.18)	(0.00, 0.01, 0.21, 0.60, 0.18)
	DF18	0.490	(0.00, 0.02, 0.27, 0.54, 0.17)	
Smart resource system-related forces (u_6)				
	DF12	0.494	(0.00, 0.02, 0.24, 0.54, 0.21)	(0.00, 0.01, 0.24, 0.51, 0.24)
	DF25	0.506	(0.00, 0.00, 0.24, 0.49, 0.27)	

6.3.2.4 Establishing the overall influence level for EPSs implementation

To develop a final fuzzy evaluation matrix of total influence level (TIL), the fuzzy matrices of PDFs ($D_{u_1}, D_{u_2}, \ldots, D_{u_6}$) were normalized with respect to their weighting functions. The MF of the TIL is shown in Table 6.6.

Table 6.6 Membership function of overall influence level

PDF Classification	Weightings for CDFs	MF for PDFs (Level-1)	MF for overall influence level
Integrity and environment-related forces (u_1)	0.220	(0.00, 0.00, 0.13, 0.36, 0.51)	(0.00, 0.01, 0.16, 0.46, 0.37)
Process optimization-related forces (u_2)	0.218	(0.00, 0.01, 0.09, 0.43, 0.47)	
Fairness and conformance-related forces (u_3)	0.158	(0.00, 0.00, 0.19, 0.42, 0.39)	
Information integration-related forces (u_4)	0.205	(0.00, 0.00, 0.19, 0.54, 0.27)	
Client-related forces (u_5)	0.099	(0.00, 0.01, 0.21, 0.60, 0.18)	
Smart resource system-related forces (u_6)	0.100	(0.00, 0.01, 0.24, 0.51, 0.24)	

Using Eq. (6.7), Eq. (6.8) and Table 6.5, the MF of the TIL can be estimated as:

$$\overline{D}_i = \begin{bmatrix} 0.220 \\ 0.218 \\ 0.158 \\ 0.205 \\ 0.099 \\ 0.100 \end{bmatrix} \times \begin{bmatrix} 0.00 & 0.00 & 0.13 & 0.36 & 0.51 \\ 0.00 & 0.01 & 0.09 & 0.43 & 0.47 \\ 0.00 & 0.00 & 0.19 & 0.42 & 0.39 \\ 0.00 & 0.00 & 0.19 & 0.54 & 0.27 \\ 0.00 & 0.01 & 0.21 & 0.60 & 0.18 \\ 0.00 & 0.01 & 0.24 & 0.51 & 0.24 \end{bmatrix} = (0.00, 0.01, 0.16, 0.46, 0.37)$$

To determine the '*TIL*' index for EPSs implementation, Eq. (6.9) is used:

$$TIL_{PDFs} = [(0.00 \times 1) + (0.01 \times 2) + (0.016 \times 3) + (0.46 \times 4) + (0.37 \times 5)] = 4.20$$

Further, a linguistic scale was generated for categorical expressions of influence levels (IL) using an expert-driven assessment technique to determine the values to support the fuzzy numbers as shown in Table 6.7 (Elbarkouky et al., 2016; Tran et al., 2012).

Table 6.7 Influence level linguistic scales

Influence level expressions	MF	Normalized MF	Index (v)	Approx. scale range
IL1-Very low (VL)	(1,0.85,0.65,0,0)	(0.4,0.34,0.26,0,0)	1.86	$v < 2.25$
IL2-Low (L)	(0.7,1,0.7,0.3,0)	0.26,0.38,0.26,0.11,0)	2.25	$2.25 \leq v < 3.21$
IL3-Moderate (M)	(0,0.6,1,0.6,0)	(0,0.3,0.5,0.3,0)	3.21	$3.21 \leq v < 3.83$
IL4-High (H)	(0,0.3,0.7,1,0.7)	0.11,0.26,0.37,0.26	3.69	$3.69 \leq v < 4.14$
IL5-Very high (VH)	(0,0,0.65,0.85,1)	(0,0,0.26,0.34,0.4)	4.14	$v \geq 4.14$

Based on Table 6.7, a summary of IL index and their linguistic expressions of the PDFs and TIL are presented in Table 6.8.

Table 6.8 Summary of influence level index for each PDF and TIL

Classifications	IL Index	Linguistic
PDF 1: Integrity and environment-related forces (u_1)	4.37	VH
PDF 2: Process optimization-related forces (u_2)	4.35	VH
PDF 3: Fairness and conformance-related forces (u_3)	4.20	VH
PDF 4: Information integration-related forces (u_4)	4.07	H
PDF 5: Client-related forces (u_5)	3.95	H
PDF 6: Smart resource system-related forces (u_6)	3.98	H
Total Influence Level (TIL)	4.20	VH

The fuzzy evaluation model shows that the TIL for the main forces driving EPSs implementation on projects was 4.20 (Table 6.8). This means that there is high tendency for EPSs to be adopted on projects when these CDFs are high within the construction project environment.

The ‘integrity and environment-related forces’ category has the highest influence of 4.37 (see Table 6.8) for driving EPSs adoption among project practitioners in the GCI. Based on four CDFs, the ‘integrity and environment-related forces’ highlights practitioners’ desire to use EPSs to improve procurement principles and ethics, while contributing to environmental sustainability in project delivery. With the increase in procurement malpractices, this finding accentuates Wimalasena and Gunatilake (2018) assertion about the lack of integrity in the procurement process affecting project deliverables in developing countries. Hence, safeguarding the integrity of procurement is key to project parties interacting with the activities of CP in the Ghanaian environment. Further, engaging EPSs from the initial stages bolsters environmental preservation efforts from inception throughout the project lifecycle. This results in efficient use of resources (e.g. less paper documentation for tendering/bidding). In developing countries, like Ghana, environmental sustainability pressures have driven some practitioners to adopt EPSs to satisfy green practice demands on projects. This suggests that efforts to improve sustainability issues are becoming vital in the developmental agenda of procurement in the GCI (Mensah and Ameyaw, 2012), and hence the contributions of EPSs towards sustainable practices can be used to promote EPSs among project professionals in the GCI.

Comprising of four forces, the 'process optimization-related forces' ranks second with 4.35 IL (Table 6.8). Optimizing the existing procurement process is deemed as essential by practitioners. This is because the procurement process provides the means for acquiring critical services and materials for accomplishing project tasks effectively. Therefore, any variation in schedule or cost impacts performance on projects significantly. Interestingly, in the Ghanaian environment, the quest to reduce process delays and cost has motivated EPSs adoption notably, as indicated by Owusu (2015). This is due to prolonged processes consistently stalling the inception of many projects while inducing additional financial burdens on project parties in Ghanaian construction environment. For instance, Santoso and Bourpanus (2019) indicated that less overheads (10% reduction) were experienced with EPSs for tendering. Achieving such savings in cost in the GCI for tendering processes would encourage competitiveness to enhance the client's value delivery on projects. Since more parameters (e.g. cost, time, materials) are needed to complete project tasks, early EPSs involvement makes positive impacts towards efficient and effective task completion.

The 'fairness and conformance-related forces' category consisting of three forces has high influence of 4.20. With respect to the complex interest of project stakeholders, having a transparent system increases stakeholders' trust and confidence in the reliability of the process.

In developing countries like Ghana, where the government is the major buyer of infrastructure projects (Anvuur et al., 2006), ensuring a fair and transparent system improves public trust. However, transparency and trust are not limited to developing countries only, EPSs also strengthen corporate trust among parties in the developed countries as well (Gardenal, 2013). In achieving fairness, EPSs facilitate compliance with regulations since there is reduction in physical interactions and error minimization. Hence, project client-oriented agencies in the GCI could encourage their partners and suppliers to adopt EPSs in improving procurement compliance and to demonstrate transparency in the process. This would in turn build stakeholders trust and promote good corporate image of the client organization.

With four CDFs, the ‘information integration-related forces’ category has an immense influence of 4.07 for encouraging EPSs uptake. The current upsurge of digital applications in the past decade, poses integration prospects for practitioners in managing information for construction procurement. The effective management of project data and archives is essential in mitigating disputes and claims among project parties. In using EPSs, professionals have easy access to share project information which facilitates decision-making at various stages of the project and improves communication. Additionally, the ameliorating opportunities digital applications bring, including the value-added services, galvanizes EPSs usage, enabling practitioners to collaborate and make apt decisions for implementation in the GCI. Although, EPSs have relatively low usage rates in Ghana like many other developing economies, its ability to provide integrating platforms could be used as a persuasive force among procurement practitioners to gradually embrace digitization in construction procurement.

The 'client-related forces' category which includes two forces has a significant IL of 3.95 in compelling practitioners to use EPSs. Satisfying the client with respect to their demands is vital for the success of construction projects and for value delivery by project managers. This means that client requirements on projects can be used to coerce EPSs implementation in the Ghanaian project environment. This suggests that the client's role on a project can be used as an influence path due to project professionals desire to satisfy the client in the GCI. Since clients' perception for satisfaction are formed through their expectations and interactions with project participants at all stages of a project, it becomes imperative for managers to use effective ways to fulfil clients' expectations. For example, in the Ghanaian case, donor-funded project clients have expectations of using effective technologies such as EPSs on projects and to facilitate fast exchange of information, hence project parties adopt EPSs into their construction processes.

The category 'smart resource system-related forces' which has an IL of 3.98 consist of two forces. The ability to work smart with access to intelligent applications for decision-making has tendencies of reducing personnel within the process. Although staff reduction may result from EPSs usage, the technological competencies of procurement staffs are enhanced to ensure a process that is efficient. Typically, the GCI has many workers within the procurement process chain, hence, digitizing procurement processes would enhance productivity as well as aid procurement personnel to access expert decisions on procurement issues through the resource tools of EPSs.

6.4 PRIORITIZED CRITERIA FOR EPSs BENEFITS QUANTITATIVE ASSESSMENTS

Based on EPSs benefits groupings in Table 6.3, a three-tier hierarchical model was conceptualized and proposed to aid the identification and prioritization of benefits that are more desired and preferred for quantitative assessment in the GCI (Fig. 6.1). The proposed model consists of the individual benefits, that is, 19 CDFs and their respective groupings (PDFs). Using the problem structure of AHP, the top-echelon of the model comprised of the 'prioritization of EPSs benefits for quantitative assessment' goal, while the middle-echelon entailed the six groupings of EPSs benefits as the main categories. The lower-echelon expands the main categories by listing the individual benefits for each category for comparison. To guide the initial AHP prioritization model development, the individual benefits for the categories were orderly organized based on their positions in Table 6.4. It is important to note that the problem for decision-makers in this AHP model is the identification and prioritization of EPSs benefits that are more feasible and desired for quantitative assessments in the GCI. To that effect, decision-makers and experts could be guided in the selection of appropriate EPSs needed in the quantitative evaluation of EPSs benefits for construction projects.

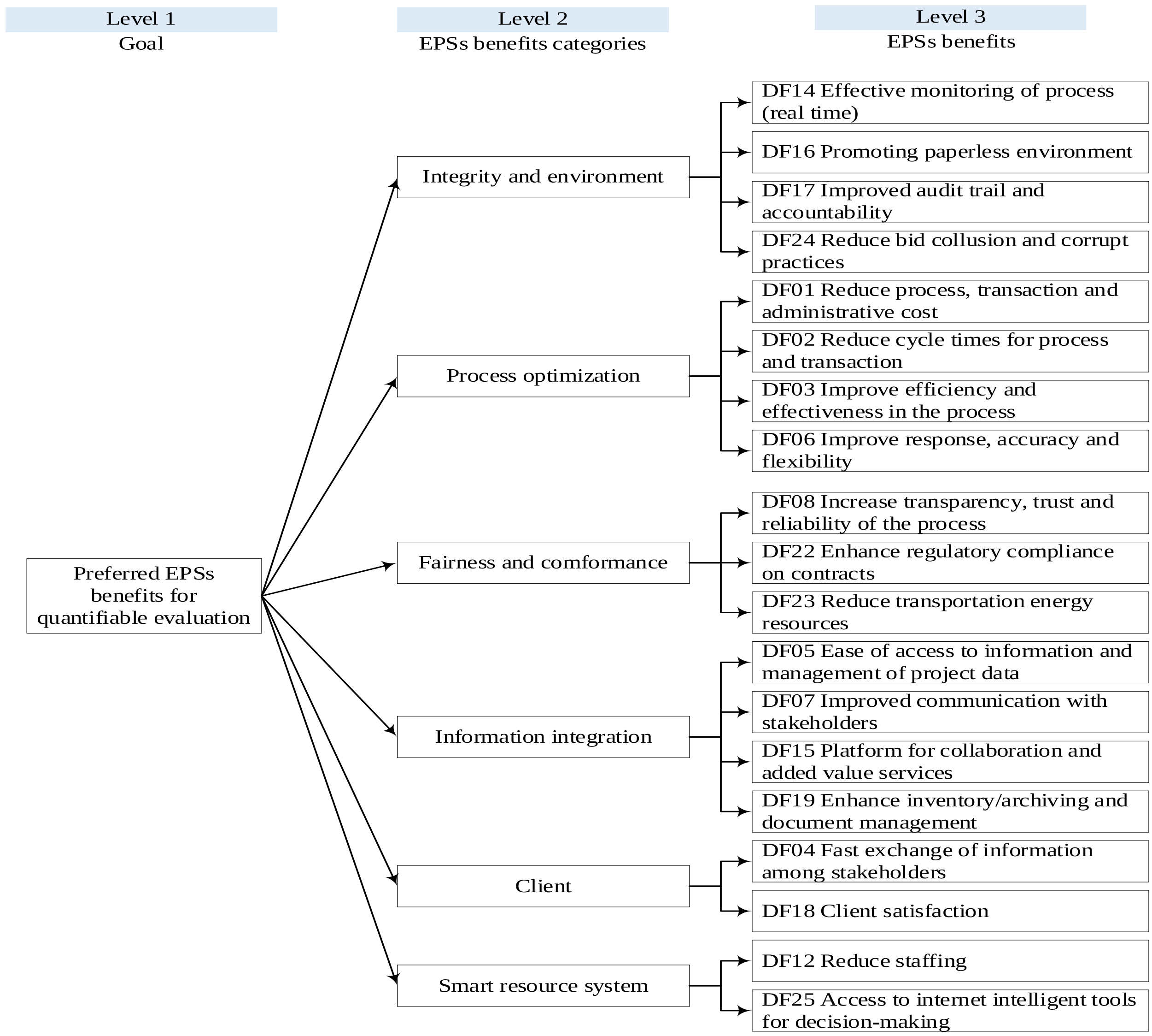

Fig. 6.1 Initial model for AHP prioritization of EPS benefits

6.4.1 AHP consistency test

To compare the individual benefits within each category for derivation of AHP weights, consistency tests were first conducted with the matrices created by reason of the benefits and their categories. As such, six different matrices were formed for respondents rating using the AHP scale (Table 6.9). For instance, the category ‘process optimization-related forces’ has four benefits, hence a 4x4 matrix is generated for this category. In measuring consistency, Saaty (1994), recommended the acceptable consistency ratio (CR) values for various sizes of matrices: thus ≤ 0.05 for 3-by-3 matrix; ≤ 0.08 for 4-by-4 matrix and; ≤ 0.10 for larger matrices. It is worth noting that CR becomes meaningful and effective in measuring consistency when the elements in a comparison judgment matrix is more than three ($n \geq 3$). This is because there is no inconsistency in a correctly built comparison judgement matrix with two elements ($n=2$), since there is only one comparison (Godinho et al., 2011). Hence, the CR for a comparison judgement matrix with $n=2$ is null and not applicable. From Table 6.9, the CR value for the 18 responses for the 3 x 3 matrix and the 4 x 4 matrix were within the acceptable values for AHP analysis.

Table 6.9 CR for comparison judgement matrices

ID	Matrix 1 (4x4)	Matrix 2 (4x4)	Matrix 3 (3x3)	Matrix 4 (4x4)	Matrix 5 (2x2)[1]	Matrix 6 (2x2)[1]
R1	0.0765	0.0465	0.0235	0.0398	-	-
R2	0.0797	0.0617	0.0425	0.0748	-	-
R3	0.0754	0.0742	0.0220	0.0684	-	-
R4	0.0740	0.0793	0.0330	0.0652	-	-
R5	0.0650	0.0641	0.034	0.0594	-	-
R6	0.0431	0.0665	0.0456	0.0567	-	-
R7	0.0530	0.0307	0.0281	0.0777	-	-
R8	0.0709	0.0707	0.0421	0.0485	-	-
R9	0.0697	0.0720	0.0202	0.0759	-	-
R10	0.0316	0.0754	0.0235	0.0735	-	-
R11	0.0709	0.0690	0.0456	0.0693	-	-
R12	0.0607	0.0576	0.0281	0.0500	-	-
R13	0.0395	0.0696	0.0220	0.0569	-	-
R14	0.0536	0.0781	0.0477	0.0596	-	-
R15	0.0395	0.0728	0.0235	0.0364	-	-
R16	0.0778	0.0735	0.0330	0.0616	-	-
R17	0.0626	0.048	0.022	0.0794	-	-
R18	0.0738	0.0264	0.0202	0.0788	-	-

[1]Note: CR values for comparison judgement matrices are not applicable.

Table 6.10 presents the mean priority weights of EPSs benefits for quantification regarding benefit evaluation in GCI. The results show varying values of weights of EPSs benefits from their respective categories in the analysis, which generally ranges from 0.0740 to 0.6202. Using Table 6.10, the top benefits from the six categories include: effective monitoring of process (real time) (DF14); reduce cycle times for process and transaction (DF02); enhance regulatory compliance on contracts (DF22); improved communication with stakeholders (DF07); client satisfaction (DF18); and access to internet intelligent tools for decision-making (DF25). For the category, integrity and environment-related forces, one explanation for effective monitoring of process (real time) (DF14) being ranked top could be that the real time monitoring of CP processes has attributes of trackers that makes it easily measurable. Also, real time monitoring provides a foundational support in the evaluation of audit trails and bid collusion. Within the process optimization-related forces category, reduce cycle times for process and transaction (DF02) was selected over cost reduction benefits for quantitative evaluation. Possible reasons could be that time has more direct measurable attributes in CP processes and further determines the improvements in efficiency which is strongly linked to cost components in CP processes.

Table 6.10 Criteria weight of benefits for quantification evaluation

Benefits categories	EPSs benefits lists	Sum of normalized weights	Mean criteria weight
Integrity and environment-related forces	DF14 – Effective monitoring of process (real time)	9.5559	0.5309
	DF16 – Promoting paperless environment	1.3328	0.0740
	DF17 – Improved audit trail and accountability	4.7365	0.2631
	DF24 – Reduce bid collusion and corrupt practices	2.3787	0.1322
Process optimization-related forces	DF01 – Reduce process, transaction and administrative cost	6.7359	0.3742
	DF02 – Reduce cycle times for process and transaction	7.4346	0.4130
	DF03 – Improve efficiency and effectiveness in the process	2.4580	0.1366
	DF06 – Improve response, accuracy and flexibility of process	1.3711	0.0762
Fairness and conformance-related forces	DF08 – Increase transparency, trust and reliability of the process	6.2794	0.3489
	DF22 – Enhance regulatory compliance on contracts	7.7111	0.4284
	DF23 – Reduce transportation energy resources	3.1660	0.1759
Information integration-related forces	DF05 – Ease of access to information and management of project data	2.9532	0.1641
	DF07 – Improved communication with stakeholders	7.1436	0.3969
	DF15 – Platform for collaboration and added value services	2.7874	0.1549
	DF19 – Enhance inventory/archiving and document management	5.3052	0.2947
Client-related forces	DF04 – Fast exchange of information among stakeholders	6.8357	0.3798
	DF18 – Client satisfaction	11.1643	0.6202
Smart resource system-related forces	DF12 – Reduce staffing	7.4929	0.4163
	DF25 – Access to internet intelligent tools for decision-making	10.5071	0.5837

Among the EPSs benefits in the fairness and conformance-related forces category, enhance regulatory compliance on contracts (DF22) benefit was desired for quantitative evaluation. This is because compliance of regulations on contracts is deemed critical to the success of CP processes and for building trust of stakeholders. With the information integration-related forces category, improved communication with stakeholders (DF07) was top-ranked for quantifiable benefit assessment since communication fuses the flow and management of information on projects. This makes the measurement of communication with stakeholders more apprehensible and representative of the information integration category. Regarding client-related forces and smart resource system-related categories, client satisfaction (DF18) and access to internet intelligent tools for decision-making (DF25) were ranked top EPSs benefits preferred for quantitative assessments. Obviously, client satisfaction has major significance in the success of CP, hence, the motivation for finding out measures/indicators to quantitatively assess it. Despite 'reduce staffing' being generally perceived as simple to measure, respondents preferred access to internet intelligent tools for quantitative measurement in the smart resource system category. Possible reason for this preference could be procurement practitioners' desire to continuously engage and apply modern digital tools in CP amidst the digitalization drive. Hence, EPSs are propelled to integrate intelligent digital technologies that would improve CP in the construction industry.

To that end, the initial model (Fig. 6.1) was revised after the AHP analysis to develop the prioritized weights and hierarchy model of EPSs benefits preferred for quantifiable evaluation (see Fig 6.2). The model developed in Fig. 6.2 has implications for policy-makers and practitioners in typical construction project environments with limited resources since the quantitative measurement of all EPSs benefits may not be feasible in construction environments. In such situations, the top benefits based on the priority weights in each category can be employed to develop a comprehensive and concise list of benefits required for benefit evaluation regarding EPSs implementation and usage on projects. For comprehensive evaluation of EPSs benefits across several benefits areas for quantification, practitioners in Ghana should first focus on effective monitoring of process (real time) (DF14); reduce cycle times for process and transaction (DF02); enhance regulatory compliance on contracts (DF22); improved communication with stakeholders (DF07); client satisfaction (DF18); and access to internet intelligent tools for decision-making (DF25).

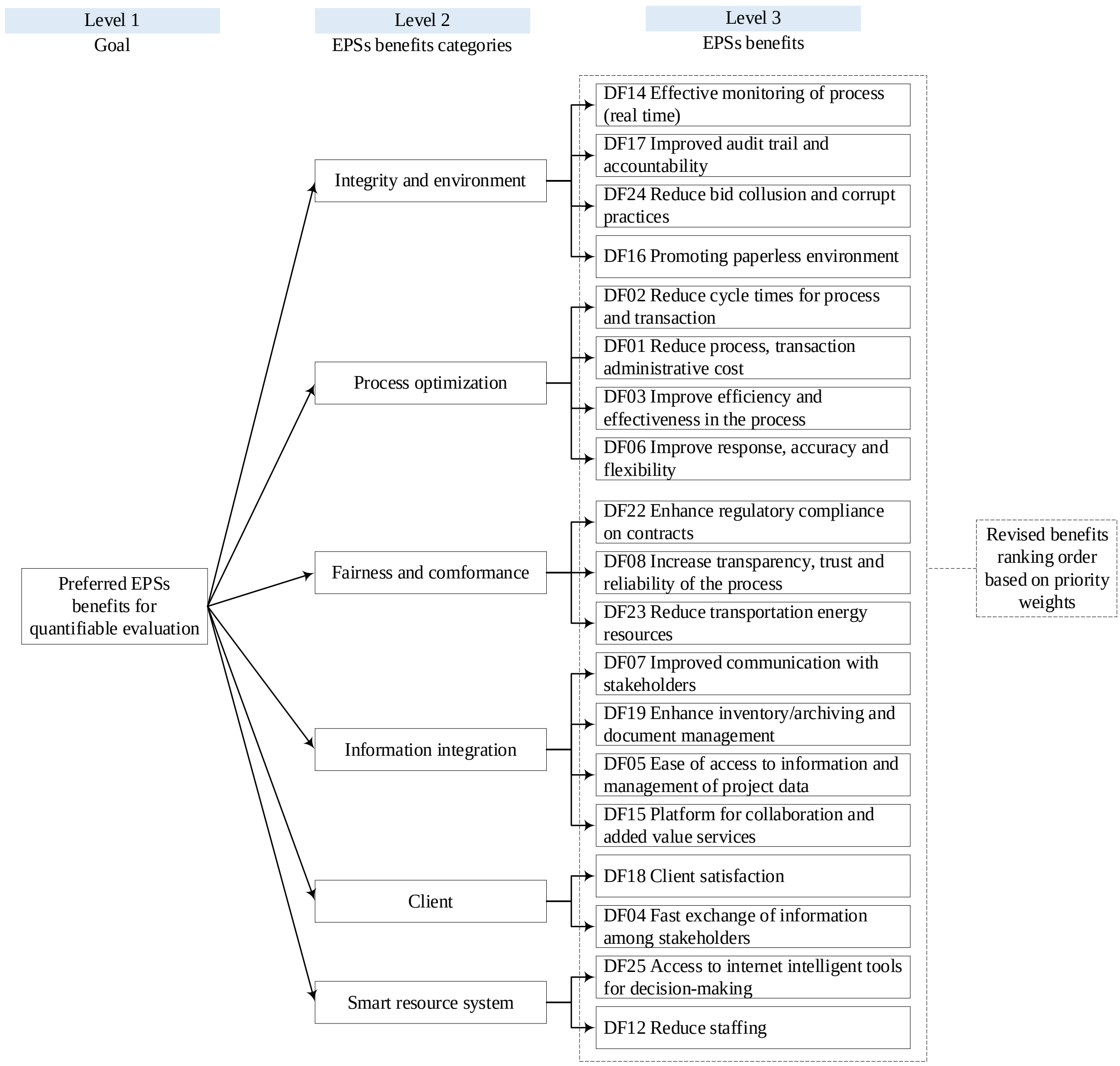

Fig. 6.2 Developed priority model for EPSs benefit for quantifiable assessments

6.5 CHAPTER SUMMARY

The benefits of EPSs have attracted practitioners' attention and motivated EPSs adoption in the construction industry due to the improvements in CP. This chapter analyzed the benefit drivers of EPSs in two parts, thus, examining the critical influences of benefit drivers and the priority evaluation of EPSs benefits for quantifiability. Therefore, several research methods involving literature review and questionnaire surveys were adopted in a multi-stage process by the use of the AHP survey to collect practitioners' experiences and views on important EPSs benefits and which of them should be evaluated. Through descriptive data analysis, 19 out of 26 benefit drivers were deemed as critical. Further, the factor analysis conducted on the critical benefit drivers data revealed six underlying groups explaining the EPSs benefit drivers phenomenon; integrity and environment-related forces, process optimization-related forces, fairness and conformance-related forces, information integration-related forces, client-related forces and smart resource system-related forces.

In addition, the FSE was used to examine the influences of these grouped benefit drivers on EPSs adoption. From the fuzzy evaluation, high influences of these six groupings, collectively generates strong forces in creating an adoption climate that encourages EPSs adoption in project environments. Although, integrity and environment, process optimization, and fairness and conformance related forces obtained higher weights from the FSE model, these three benefits drivers groups would need additional support from the other remaining benefits to strongly influence practitioners to adopt EPSs.

The findings of this study have implications for practice and research. The tool developed contributes to EPSs research by providing a novel approach that enhances quantitative assessment of an uncertain project environment's suitability for EPSs acceptance in decision-making. This study provides researchers with new insights on DFs groups that are influential in stimulating an enabling environment for EPSs implementation. Furthermore, a decision-support tool could be developed for practitioners to conduct better forecasting decisions regarding EPSs acceptability by incorporating the influential DFs from a wide array of factors pertinent to project situations. The added value lies in the decision-support tool's flexibility in combining the different DFs using weight coefficients in a reliable methodological process. Hence, practitioners can use the developed decision-support tool based on the peculiar conditions to optimize EPSs uptake decision-making.

For practice, the identification of the influential DFs provides knowledge to policy makers and practitioners on what to focus on when creating a stimulating project environment for EPSs uptake. For instance, project managers planning the implementation of EPSs in uncertain project environments could assess the influential DFs through project demands, project characteristics, stakeholders' values and interactions to enhance decision-making on EPSs acceptability. To that end, the procurement managers in government agencies are informed about the essential areas required by their project stakeholders to use EPSs. This information could be leveraged in the development of EPSs for various project portfolios to improve and sustain EPSs usage on projects.

These findings equip project managers of private clients with valuable information to improve decision-making on whether to continue investing in the EPSs or suspend the implementation process and divert attention to creating an enabling environment that is suitable for EPSs acceptance. The suitable project environment could be formed by developing strategic actions based on the influential DFs needing improvements.

In prioritizing EPSs benefits preferred for quantitative assessments, the results from the AHP analysis showed that effective monitoring of process (real time), reduce cycle times for process and transaction, enhance regulatory compliance on contracts, improved communication with stakeholders, client satisfaction, and access to internet intelligent tools for decision-making had the top priority weights from the respective six groupings of EPSs benefits. These results were subsequently used to develop a decision model for practitioners in selecting the benefits that comprehensively represents the EPSs benefits and could be quantified in typical project environments with limited resources.

CHAPTER 7 ANALYSIS AND RESULTS – MODELLING THE INFLUENCES OF BARRIERS TO EPSs IMPLEMENTATION IN CONSTRUCTION PROJECTS[8]

7.1 INTRODUCTION

This chapter presents the barriers to EPSs implementation in the construction industry. While the previous chapter examined the benefit drivers of EPSs and the prioritized benefits for quantifiable evaluation, the present chapter analyzes the dynamic influences of barriers to the implementation of EPSs in Ghanaian construction projects. After data collection, as indicated earlier, preliminary analysis was conducted to rank the critical factors for the barriers of EPSs. Subsequently, factor analysis was conducted to uncover the underlying groups of barriers hindering EPSs implementation on projects and to serve as input parameters for the modelling of interrelationship influence patterns. The NFS was adopted to determine and predict the influences of the barrier groups. Afterwards, sensitivity analysis was applied using the NFS model developed to determine patterns of influences arising from the complex interrelationships of barrier groups. From this analysis, the synergistic effects and behaviors of barrier groups on hindering EPSs implementation in the Ghanaian project environment were discussed.

7.2 DATA ANALYSIS AND RESULTS FOR EPSs BARRIERS

The data collected in this study was subjected to preliminary checks. To assess the reliability of the survey instrument, the Cronbach's alpha technique was adopted. The overall coefficient α value of the 21 barriers in this study was 0.797, which indicates that there is high reliability

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[8] This chapter is largely reported in
Yevu S. K., Yu A. T. W., Darko A., and Nani, G. (Under review). Modeling the influence patterns of barriers to electronic procurement technologies usage in construction projects. *Engineering, Construction and Architectural Management*. Manuscript ID: ECAM-01-2021-0013

and consistency of the survey instrument (Field, 2013). For data normality test, the Shapiro-Wilk (SW) test for the 21 barriers showed *p-values* less than 0.05, hence, the study's dataset is not normally distributed (Royston ,1992).

7.2.1 Critical Barriers to EPSs Implementation

The results of the mean analysis for the barriers to EPSs are summarized in Table 7.1. The mean scores denoting the influence of the barriers ranged from 3.09 to 4.68 and barriers with normalized scores not less than 0.50 were identified as critical barriers to EPSs implementation on projects.

Table 7.1 shows that 15 out of the 21 barriers were deemed as critical since their normalized values were not less than 0.50. The barrier "resistance to change attitude" (B02) with the highest mean value (4.68) was ranked first, indicating that attitudinal change is the most critical barrier hindering EPSs on projects within the Ghanaian project environment. This finding concurs with some previous studies about strong resistance to new technology use within the construction industry (Liu et al., 2018; Wimalasena and Gunatilake, 2018), and also reveals the current high levels of resistance to technology implementation. The second rank was "unreliable internet service and power supply" (B04) with mean value of 4.60, followed by "lack of IT infrastructure and capability" (B07) (mean = 4.58) in the third rank by all respondents. "Insufficient management support for EPSs" (B17) with mean value (4.54) ranked fourth and "unreadiness of business partners" (B18) ranked fifth with a mean value of 4.18 to sum up the top five critical barriers hindering EPSs regarding developing countries.

The Kendall's *W* value for ranking the 21 barriers was 0.276 at significance level of 0.000, suggesting that there is substantial level of agreement on the ranking of barriers among the three respondent groups. The Kruskal-Wallis test shows that 16 barriers had no significant difference statistically (significance > 0.05), and five barriers had statistically significant difference in the ranking among the respondent groups (i.e. consultants, contractors, regulatory agencies). The consultant and contractor groups rated "unreliable internet service and power supply" and "unreadiness of business partners" as high critical barriers however the regulatory personnel group had lower rating for these two barriers. Also, while consultants and contractors viewed "violations of data integrity and possibility of data loss" as highly critical, the regulatory personnel group had lower ranking of its criticality. This could be because the regulatory agencies are partly involved in the provision of EPSs services in the construction industry.

Table 7.1 Mean analysis of barriers to EPSs implementation in construction projects

Code	All respondents				Consultant			Contractor			Regulatory Agency			Kruskal-Wallis
	Mean	SDv	Normalization[a]	Rank	Mean	SDv	Rank	Mean	SD	Rank	Mean	SDv	Rank	Test
B02	4.68	0.622	1.00[b]	1	4.74	0.474	1	4.82	0.390	2	4.37	0.967	1	0.128
B04	4.60	0.714	0.95[b]	2	4.68	0.501	2	4.89	0.315	1	4.07	1.107	7	0.001[d]
B07	4.58	0.704	0.94[b]	3	4.61	0.630	3	4.71	0.460	4	4.37	1.006	2	0.666
B17	4.54	0.659	0.91[b]	4	4.56	0.611	4	4.68	0.476	5	4.33	0.877	3	0.422
B18	4.28	0.924	0.75[b]	5	4.30	0.841	5	4.75	0.518	3	3.74	1.163	13	0.000[d]
B03	4.26	0.772	0.74[b]	6	4.27	0.714	6	4.54	0.744	6	3.96	0.854	8	0.220
B13	4.19	0.897	0.69[b]	7	4.23	0.837	7	4.11	0.875	10	4.19	1.075	4	0.747
B06	4.02	0.866	0.58[b]	8	3.98	0.832	11	4.21	0.630	7	3.89	1.121	9	0.541
B10	3.96	0.800	0.55[b]	9	4.00	0.784	10	3.75	0.518	16	4.07	1.035	6	0.173
B21	3.94	0.788	0.54[b]	10	3.85	0.808	15	4.00	0.720	12	4.11	0.801	5	0.374
B16	3.92	0.726	0.52[b]	11	3.89	0.636	14	4.21	0.686	8	3.67	0.877	14	0.030[d]
B14	3.91	0.730	0.52[b]	12	3.94	0.762	12	4.00	0.544	11	3.74	0.813	12	0.339
B08	3.89	0.762	0.51[b]	13	4.02	0.734	8[c]	3.68	0.548	17	3.81	0.962	11	0.082
B19	3.90	0.779	0.51[b]	14	3.92	0.730	13	3.89	0.916	15	3.85	0.770	10	0.887
B05	3.90	0.841	0.51[b]	15	4.02	0.734	8[c]	4.18	0.612	9	3.33	1.038	19	0.001[d]
B01	3.69	0.764	0.38	16	3.68	0.705	16	3.89	0.685	14	3.48	0.935	16	0.201
B15	3.60	0.862	0.32	17	3.68	0.826	17	3.93	0.604	13	3.04	0.940	20	0.000[d]
B11	3.55	0.695	0.29	18	3.59	0.701	18	3.54	0.576	20	3.44	0.801	17	0.676
B09	3.54	0.827	0.28	19	3.55	0.826	19	3.61	0.832	18[c]	3.44	0.847	18	0.840
B20	3.41	0.833	0.20	20	3.30	0.841	20	3.61	0.832	18[c]	3.48	0.802	15	0.260
B12	3.09	0.742	0.00	21	3.09	0.799	21	3.18	0.612	21	3.00	0.734	21	0.743

Note: SDv = Standard Deviation.

[a]Normalization = (Mean – Minimum Mean) / (Maximum Mean – Minimum Mean);

[b]The normalized value indicates that the barrier is critical (normalized value ≥ 0.50);

[c]Mean values with the same standard deviation;

[d]The Kruskall-Willis test value is significant at the ≤ 0.05 significance level. The Shapiro-Wilk test value for all 21 barriers were ≤ 0.05 significant level. The Kendall's *W* for the 21 barriers was 0.267 with significance level of 0.000.

7.2.1.1 Global perspectives: Ghana, Hong Kong and selected developed economies.[9]

As mentioned earlier, a survey was conducted on developed economies to enhance comparisons with the mean results of this study as shown in Table 7.2. From Table 7.2, three barriers appeared in the top five ranks between Ghana, Hong Kong and the selected developed countries, thus, resistance to change attitude, insufficient management support for EPSs and unreadiness of business partners. Despite resistance to change and insufficient management support being extensively highlighted in EPSs literature, the identification of unready project partners across the Ghana, Hong Kong and selected developed economies contexts, offers valuable insights on the impact of project partners preparedness in developing economies as well as developed economies.

Although '*unreliable internet service and power supply*' and '*lack of information technology infrastructure and capability*' were ranked second and third respectively in Ghana, they were least ranked in Hong Kong and the selected developed economies. This suggests that, reasonably, the issues of internet connectivity and infrastructure are prevalent in developing economies. However, Hong Kong and the selected developed economies highly rated '*lack of trust and confidentiality*' as compared to its eighth ranking among the Ghanaian project professionals. Possible reason could be that EPSs have been in use in Hong Kong and the selected developed economies for some years, hence, user concerns about confidentiality amidst current cybersecurity threats have affected the levels of trust with EPSs usage on construction projects among stakeholders. On the contrary, since EPSs usage is at nascent stages across Ghana, practitioners' concern about the trust and confidentiality of EPSs are yet

[9] Partially reported in Yevu, S. K., Yu, A. T. W., Nani, G., Darko, A., and Tetteh, M. O. (2021d). Electronic procurement systems in construction procurement: Global experiences of barriers and strategies. *Journal of Construction Engineering and Management*. Manuscript ID: COENG-11130R1(In press).

to be fully tested on a wider scale. Notwithstanding, its eighth ranking from the Ghanaian perspective still indicates some significant level of uneasiness with EPSs use in Ghanaian projects. From the Ghanaian perspective, electronic authentication and authorization issues, and high cost of EPSs investment were deemed important barriers, however, these barriers were ranked low in Hong Kong and the selected developed economies. Addressing such barriers in the developing economies context would aid the promotion of EPSs in CP among project organizations.

Table 7.2 Comparison of top 10 barriers to EPSs between Ghana, Hong Kong and selected developed economies

Barriers to EPSs implementation	Ghana		Hong Kong		Selected Developed Economies[a]	
	Mean	Rank	Mean	Rank	Mean	Rank
B02 - Resistance to change attitude	4.68	1[b]	4.47	1[b]	4.03	3[b]
B04 - Unreliable internet service and power supply	4.60	2[b]	2.35	19	2.37	19
B07 - Lack of IT infrastructure and capability	4.58	3[b]	3.29	16	2.94	16
B17 - Insufficient management support for EPSs	4.54	4[b]	4.24	2[b]	3.57	5[b]
B18 - Unreadiness of business partners	4.28	5[b]	3.82	4[b]	4.03	2[b]
B03 - Electronic authentication and authorization issues	4.26	6	3.41	13	3.20	11
B13 - High cost of EPSs investment	4.19	7	2.82	18	3.00	15
B06 - Lack of trust and confidentiality of the electronic system	4.02	8	3.82	5[b]	3.80	4[b]
B10 - Lack of electronic contract enforcement	3.96	9	3.82	6	3.20	10
B21 - Lack of incentives for EPSs adoption	3.94	10	3.65	8	3.11	13

Note: [a] = United States, United Kingdom and Australia.
[b] = EPSs barriers appearing in top five ranks of the selected countries/territories.

7.2.2 Classification of Barriers to EPSs

To better understand the various critical barriers identified, the FA technique was adopted to group the underlying dimensions. Appropriateness tests, that is, KMO and Bartlett's test of sphericity was conducted. The KMO value of 0.761 was obtained in this study, and it was acceptable as it satisfied the threshold of 0.50 and above (Hair et al, 2009) (Table 7.1). The value of the Bartlett's test was 525.50 at 0.000 significance level, suggesting that the correlation matrix is not an identity matrix (Pallant, 2011). Since the two tests indicate the suitability of the dataset for FA, factor extraction was conducted with principal component analysis using varimax rotation. Components with eigenvalues ≥ 1 and variables with factor loadings more than 0.50 were retained due to their significant contribution to the factor group. Five component groups were extracted accounting for 64% of variance (satisfying > 50% variance) (Field, 2013). This indicates that the five components can adequately represent the barriers to EPSs use. From Table 7.3, the five components are named: (1) human-related barriers; (2) technological risk-related barriers; (3) government-related barriers; (4) industry growth-related barriers; and (5) financial-related barriers. The five barrier groups (BGs) are used as input parameters for the neuro-fuzzy system to examine the complexities and influences of these BGs to EPSs use.

Table 7.3 Classification of barriers to EPSs

Code	Barriers to EPSs application	Barrier classification				
		1	2	3	4	5
BG 1: Human-related barriers						
B02	Resistance to change attitude	0.789	-	-	-	-
B16	Lack of demonstration of firms achieving benefits	0.784	-	-	-	-
B17	Insufficient management support for EPSs	0.645	-	-	-	-
B18	Unreadiness of business partners	0.706	-	-	-	-
BG 2: Technological risk-related barriers						
B03	Electronic authentication and authorization issues	-	0.808	-	-	-
B04	Unreliable internet service and power supply	-	0.572	-	-	-
B05	Violations of data integrity and possibility of data loss	-	0.686	-	-	-
B07	Lack of IT infrastructure and capability	-	0.577	-	-	-
BG 3: Regulation-related barriers						
B08	Lack of legal rules and regulations for EPSs	-	-	0.877	-	-
B10	Lack of electronic contract enforcement	-	-	0.660	-	-
BG 4: Industry growth-related barriers						
B19	Uncertainty of EPSs technology maturity	-	-	-	0.833	-
B21	Lack of incentives for EPSs adoption	-	-	-	0.754	-
BG 5: Financial-related barriers						
B13	High cost of technology investment	-	-	-	-	0.641
B14	Fear for reducing bribery and procurement malpractices	-		-	-	0.653
Eigenvalue		4.334	1.835	1.347	1.180	1.000
Variance (%)		19.231	14.926	11.445	9.731	9.094
Cumulative variance (%)		19.231	34.157	45.602	55.332	64.426

Note: Extraction method = principal component analysis; Rotation method = Varimax with Kaiser normalization

7.2.3 Neuro-Fuzzy System (NFS) Model for Barriers influences

As mentioned earlier, the learning structure element (LSE) of the NFS determined the input and output variables functions, and then generated the if-then fuzzy rule sets from the input/output dataset. These fuzzy rules and variables were then employed in determining the learning parameter element (LPE) structure in the NFS.

The input and output variables were obtained from the field dataset in this study. The input variables (IVs) for the NFS were derived from the BGs in Table 7.3. Hence, IV_1 – Human-related barriers, IV_2 – Technological risk-related barriers, IV_3 – Government-related barriers, IV_4 – Industry growth-related barriers, and IV_5 – Financial-related barriers. The aggregate weight mean (AWM) representing the IV's influences was derived using the formula in Eq. (7.1):

$$AWM_k = \frac{1}{h}\sum_{i=1}^{h} v_{ki} \qquad (7.1)$$

where AWM_k is the score of kth group of IV_k ($k = 1, 2, \ldots 5$), and v_{ki} is the ith barrier score of the kth IV group, and h is the number of barriers within the IV.

All IVs were evaluated by a set of three fuzzy values, that is, low (L), medium (M) and high (H). Values for IV_1 through to IV_5 were obtained from respondent's evaluation of the observed variables using the rating scale and the *AWM* developed in the study. Each fuzzy value obtained is a fuzzy set determined by a membership function (MF) (Gerek, 2014). Among the commonly adopted MFs includes trapezoidal functions, gaussian functions and triangular functions. However, this study adopted the Gaussian functions due to its good ability of achieving smoothness and avoiding zero in the denominator of a MF (Jin, 2011).

The initial MFs and value parameters are shown in Table 7.4. The output variable (OV) of the model is the level of hinderance experienced to EPSs implementation. The possible value of the OV ($f \in \{1, 2, 3, 4, 5\}$), where $\{1, 2, 3, 4, 5\}$ expresses the rating scale for the impact level ranging in a continuum from 1 denoting low level, through 3 denoting medium level to 5 denoting high level. Since the first-order Sugeno-type fuzzy inference system (FIS) was used in the neuro-fuzzy system, the OV's total number of MFs is the same as that of the fuzzy if-then rules generated with the fuzzy rule sets as presented subsequently. The OV's MFs are described as $f_i = p_i x_1 + q_i x_2 + r_i x_3 + s_i x_4 + t_i x_5 + z_i$, in which *i* denotes fuzzy if-then rules and $(p_i, q_i, r_i, s_i, t_i, z_i)$ are the consequent parameter set of the *i*th fuzzy if-then rule. Based on the target output of a corresponding data pair, consequent parameters were initialized with each set respectively before being used in the LPE. For the initial values, parameter (z_i) is designated with the target output value while the remaining parameters are designated with zero. For example, a data pair with target output value of 3 in this study, the initial consequent parameter set for the data pair is {0, 0, 0, 0, 0, 3}.

In this study, the fuzzy rules from numerical input/output dataset are generated from a straightforward method, since identified concise rules provide a network structure that enable the learning processes to be reliable, fast and more intuitive (Kim and Kasabov, 1999). This reduces the training time which is characteristic of neural network techniques and easy to modify (Jin, 2011). In three steps, the method proposed by Wang and Mendel (1992) was adapted in this study. First, for each input value of a given pair of data, the MFs are determined for all fuzzy values of the corresponding variable. Given an input/output data pair for Example 1 = (4.0, 4.5, 3.0, 3.5, 2.0 and 3.0), the first five and last numbers are the input and output values respectively. Table 7.4 shows the computational outcome of the first step as the membership value. Second, each input value is assigned a fuzzy value corresponding to the maximum membership value that the input value belongs. Given the input/output data pair of Example 1, Table 7.4 indicates the input values (IV_1 to IV_5) and the assigned fuzzy values as high, high, medium, medium, medium. Third, one rule is developed for any given pair of input/output data pair. Using Example 1, the rule is established as:

IF IV_1 = high, and IV_2 = high, and IV_3 = medium, and IV_4 = medium, and IV_5 = medium, THEN OV is $f_1 = p_1 \text{x } 4.0 + q_1 \text{ x } 4.5 + r_1 \text{ x } 3.0 + s_1 \text{ x } 3.5 + t_1 \text{ x } 2.0 + z_1 = 3$. Through this method, a total of 243 rules were created for the neuro-fuzzy system.

Table 7.4 Developing the "IF" Part of a Fuzzy If-Then Rule of input values using example 1.

Fuzzy variable	Code (Value)	Initial MF $\mu(x;\ \sigma, c)$	Numerical value	Membership value (fuzzy value)	Assigned fuzzy value
IV_1	H (High) M (Medium) L (Low)	$e^{[-(x-5)^2]/[2(0.58)^2]}$ $e^{[-(x-3.63)^2]/[2(0.58)^2]}$ $e^{[-(x-2.25)^2]/[2(0.58)^2]}$	4.0	0.845(H) 0.136(M) 0.018(L)	High
IV_2	H (High) M (Medium) L (Low)	$e^{[-(x-5)^2]/[2(0.64)^2]}$ $e^{[-(x-3.5)^2]/[2(0.64)^2]}$ $e^{[-(x-2)^2]/[2(0.64)^2]}$	4.5	0.918(H) 0.064(M) 0.018(L)	High
IV_3	H (High) M (Medium) L (Low)	$e^{[-(x-5)^2]/[2(0.64)^2]}$ $e^{[-(x-3.5)^2]/[2(0.64)^2]}$ $e^{[-(x-2)^2]/[2(0.64)^2]}$	3.0	0.600(H) 0.382(M) 0.018(L)	Medium
IV_4	H (High) M (Medium) L (Low)	$e^{[-(x-5)^2]/[2(0.53)^2]}$ $e^{[-(x-3.75)^2]/[2(0.53)^2]}$ $e^{[-(x-2.5)^2]/[2(0.53)^2]}$	3.5	0.436(H) 0.518(M) 0.045(L)	Medium
IV_5	H (High) M (Medium) L (Low)	$e^{[-(x-5)^2]/[2(0.74)^2]}$ $e^{[-(x-3.25)^2]/[2(0.74)^2]}$ $e^{[-(x-1.5)^2]/[2(0.74)^2]}$	2.0	0.900(H) 0.091(M) 0.009(L)	Medium

7.2.3.1 ANFIS Model Training for the Barriers

The dataset gathered in this study was used for training and evaluation of the model. The training set was divided into two disjoint datasets, thus training estimation sub-set for enhancing model selection and model testing sub-set for validating the model. The multi-fold cross-validation method was used to split the datasets for training in this study. Out of 121 datasets in this study, a total of 110 datasets were employed to train the model using 85-15 percent ratio (i.e. 85% for training estimation and 15% for model validation). For each round of training, a different pair of datasets (15%) was left out for model validation, and this iteration process was repeated many times.

As a result, Table 7.5 shows the summary of 10 models trained with the datasets in ANFIS. Using RMSE for model estimation and validation for best performing model for the barriers to EPSs, from Table 7.5, model 10 is selected as best model since it had the least mean square error (MSE) and RMSE values to evaluate the performance of the NFS model.

Table 7.5 Training results of neuro-fuzzy model

Neuro-fuzzy model	$MSE_{est.}$	$MSE_{val.}$	$RMSE_{est.}$	$RMSE_{val.}$
Model 1	0.00574	0.42062	0.07576	0.64855
Model 2	0.00585	1.01916	0.07647	1.00953
Model 3	0.00605	0.65933	0.07776	0.81199
Model 4	0.00555	0.98689	0.07450	0.99343
Model 5	0.00550	2.24377	0.07414	1.49792
Model 6	0.00544	0.68548	0.07376	0.82794
Model 7	0.00570	0.33536	0.07547	0.57911
Model 8	0.00574	1.39448	0.07576	1.18088
Model 9	0.00574	1.30642	0.07576	1.14299
Model 10	0.00570	0.31937	0.07547	0.56513

7.2.3.2 Model Performance Evaluation

The performance evaluation of the neuro-fuzzy model was based on the evaluation dataset. The evaluation dataset, which was different from the validation dataset, consists of 11 data cases reserved from the total data sample obtained in this study. The results of the performance indexes (i.e. RMSE, MPE and MAPE) used for model evaluation are presented in Table 7.6. The set of IVs values for each evaluation data pair were entered into the trained neuro-fuzzy model, respectively. The predicted hindrance levels by the neuro-fuzzy model were evaluated with the observed hindrance levels in this study. The evaluation results of the model are shown in Table 7.6 and Fig. 7.1.

Table 7.6 Evaluation of model predicted values with observed values

Data case	Observed value	Predicted value	$E_{eval.}$
1	4	4.0071	-0.0071
2	5	4.9667	0.0333
3	5	5.0018	-0.0018
4	5	5.0000	0.0000
5	4	3.2762	0.7238
6	3	3.3095	-0.3095
7	4	4.0446	-0.0446
8	3	0.7909	2.2091
9	4	3.9999	0.0001
10	3	3.1211	-0.1211
11	5	4.2311	0.7689
Model RMSE = 0.74521648			
Model MPE = 8.3723939			
Model MAPE = 11.22363636			

Note: $E_{eval.}$ = Error margin in neuro-fuzzy model prediction.

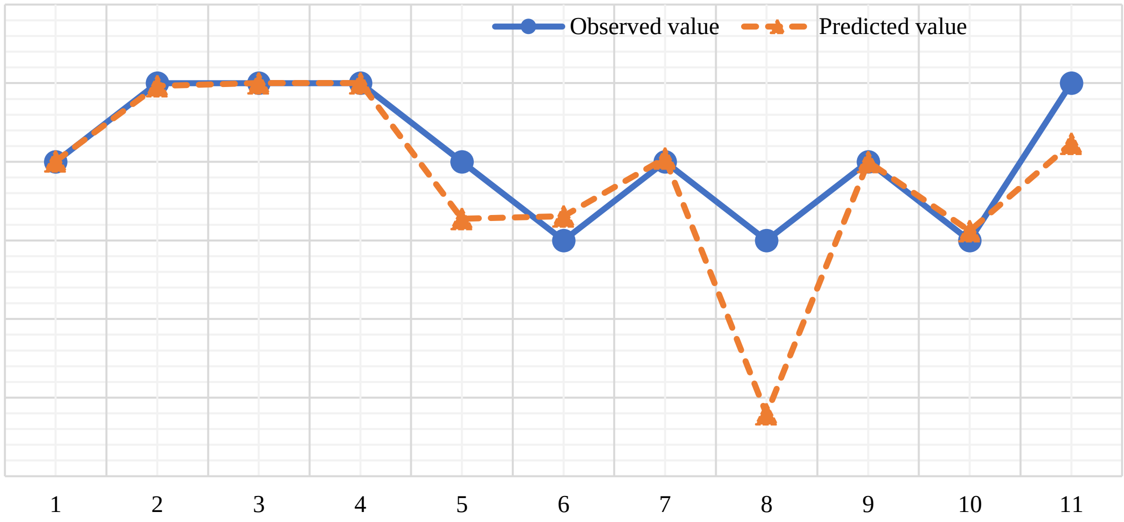

Fig. 7.1 Model performance evaluation

The evaluation results of the neuro-fuzzy model show low values for each performance index, indicating that the model has significant capabilities to predict the level of hinderance to EPSs implementation. In effect, 8 out of 11 (about 73%) data cases were predicted accurately by the neuro-fuzzy model (see Table 7.6). The performance indexes suggest that an error of ±0.745 may be generated on average by the model and may have little over forecasting (+8.4%) with an average error of 11.22% contained in the forecast. Due to the uncertain and subjective nature of experts' judgements, the neuro-fuzzy model developed with about 73% prediction accuracy, was deemed as effective to better capture the underlying nonlinear dynamics of the barriers' influence on EPSs implementation for adequate prediction.

7.2.3.3 Sensitivity analysis for barriers interrelationship influences

Sensitivity analysis examines the various influence degrees of inputs on the output of a model (Ikram, 2020). In this study, to enhance better understanding of the complex dynamics of barriers, sensitivity analysis was conducted to show the different hinderance levels arising from various combinations of inputs. In conducting sensitivity analysis, values of selected inputs are varied while the other inputs are kept at their desired values (El-Gohary et al., 2017). For purposes of examining the hindrance levels from subjective barrier judgements, the barrier inputs are derived from the MF ranges and assigned values from Table 7.4. This enables linguistic expressions (assigned values) to adequately represent the uncertain and imprecise experiences within the project environment. The sensitivity analysis was conducted in two parts (see Table 7.7). On one side, each input value represented by an assigned value, was varied to a medium influence while keeping the other inputs at high influence respectively. On the other side, paired inputs were varied to medium influence alternatively and the output values were recorded. Fig. 7.2 and Fig. 7.3 shows the influence patterns of grouped barriers comprising the hindrance level (HL) to EPSs implementation in projects.

Table 7.7 Sensitivity analysis using neuro-fuzzy model

Single BG variations						Paired BGs variations					
BG1	BG2	BG3	BG4	BG5	Output (Assign value)	BG1	BG2	BG3	BG4	BG5	Output (Assign value)
M	H	H	H	H	4.060 (H)	M	M	H	H	H	3.001 (M)
H	M	H	H	H	5.000 (H)	M	H	M	H	H	3.002 (M)
H	H	M	H	H	3.999 (H)	M	H	H	M	H	2.545 (L)
H	H	H	M	H	4.001 (H)	M	H	H	H	M	2.929 (M)
H	H	H	H	M	3.834 (H)	H	M	M	H	H	4.468 (H)
						H	M	H	M	H	3.005 (M)
						H	M	H	H	M	3.089 (M)
						H	H	M	M	H	3.998 (H)
						H	H	M	H	M	3.516 (M)
						H	H	H	M	M	4.000 (H)

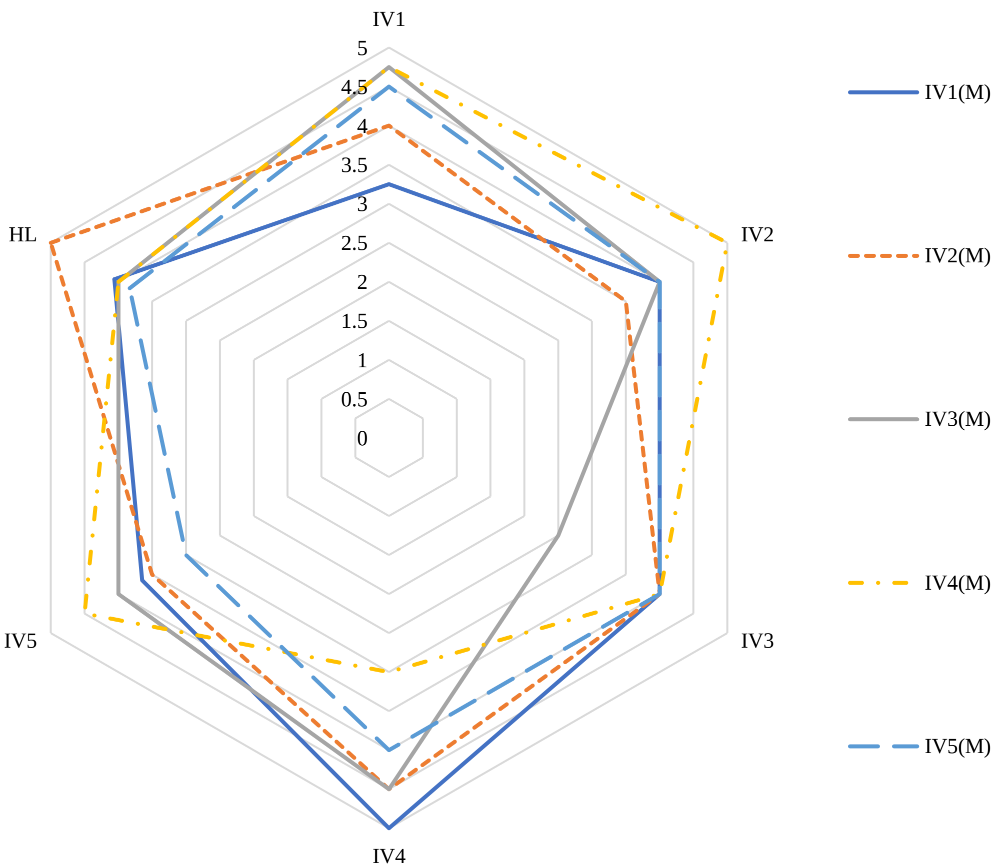

Fig. 7.2 Influence patterns of barrier groups variations

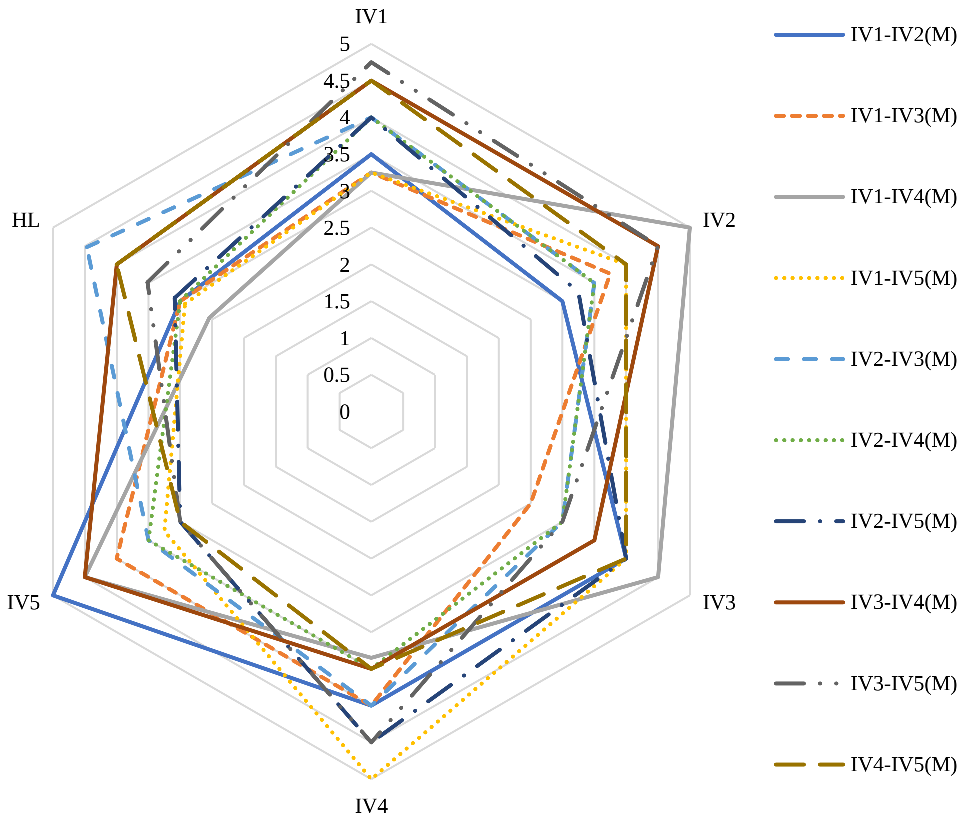

Fig. 7.3 Influence patterns of paired barrier groups variations

7.2.4 Discussions of Findings on influences of barrier interrelationships

The uptake and implementation of a technological innovation is influenced by the organization's ability to mitigate or remove the barriers (Altuwajri and Khorsheed, 2012). According to Table 7.6, generally, the model's hindrance effect is high although influences of particular BGs were varied to medium levels. This suggests that there are strong influence relationships among the barrier groups and combating or mitigating a single barrier group will not lessen the forces militating against EPSs implementation on projects. Although human-related barriers (BG1) and technological risks related-barriers (BG2) have been predominantly identified by previous studies (Liu et al., 2018; Wimalasena and Gunatilake, 2018, Kang et al., 2015), this study's findings indicate that separately reducing BG1 and BG2 still presents a high level of hindrance when the remaining BGs are high. It is not surprising that past literature identifies human-related barriers as a major barrier due to its negative impact on technology adoption and usage (Liu et al., 2018; Pala et al., 2016). Hence, there is the tendency for decision-makers and practitioners to focus on tackling human-related barriers while other equally potent BGs hinder EPSs implementation in projects. However, from the results of paired BGs with medium influences in Table 7.6, dynamic relationships and influence patterns were identified to have significant impact on the level of hindrance to EPSs implementation.

With medium influence of human-related barriers (BG1) and technological risk-related barriers (BG2)/government-related barriers (BG3), the hinderance to EPSs implementation is reduced to medium levels. This means that in project situations with less prevalent influences of BG1 and BG2/BG3, there is high possibility of implementing EPSs on projects with less resistance. This finding reveals the weight of relationships existing between BG1 and BG2/BG3 in determining the complex behavior of barriers to EPSs implementation. Human-related barriers which includes resistive attitudes to change (Liu et al., 2018), unsupportive top management (Ozorhon et al., 2016) and unready partners (Zunk et al., 2014) shows the extent of behavioral influence within the hinderance composition. Coupling the human-related barriers and technological risk-related barriers present a strategic approach for reducing the hinderance level since the technology's integrity is of concern to the users. In addition, human-related barriers paired with government-related barriers depict the connection between individual and organizational behaviors with regulation enforcements. That is, minimizing the influence of resistive behaviors and unenforced regulations surrounding EPSs implementation significantly minimizes the total effect of forces against EPSs implementation. Notably, when the influences of human-related barriers combined with industry growth-related barriers are reduced, the hindrance is low indicating high possibilities of implementing EPSs. This could be because by reducing the influence of industry growth-related barriers, thus technological integration, interoperability and maturity are improved to gain practitioners confidence of future developmental needs within the industry. When the human-related barriers and financial-related barriers have reduced influences, the total effect of hindrance to EPSs implementation reduces. Hence, the relationship between practitioners' behavior and their economic status is vital when tackling the barriers to EPSs implementation.

From the findings in this study, reducing the influence of technological risk-related barriers (BG2) and government-related barriers (BG3) still presents high levels of hindrance to EPSs implementation. This finding partly deviates from the notion that tackling technological difficulties and legal enforcements are adequate for removing challenges to EPSs use (Wimalasena and Gunatilake, 2018; Aibunu and Al-Lawati, 2010; Eadie et al., 2011). However, reducing the combined influence of technological risk-related barriers and industry growth-related barriers decreases hindrance levels. This shows the varying interrelationships among the BGs, since BG2-BG3 carry less influence weight compared to BG2-BG4. Similarly, decreasing technological risk-related barriers and financial-related barriers increases the tendencies of implementing EPSs with less challenges. This suggests that largely, tackling BG2 with other BGs generates significant weight to improve the chances of minimizing the challenges to EPSs use.

With government-related barriers (BG3) and industry growth-related barriers (BG4), addressing their influences to medium levels still offers high levels of obstacles to EPSs implementation. This indicates that mapping out the developmental needs and providing regulations only for EPSs implementation does not smoothen the challenges facing EPSs use on projects. On the contrary, focusing on government-related barriers and financial-related barriers (BG5) has significant gains of lowering the level of hindrance to EPSs implementation. This suggests that governments can play a role in lessening the challenges to EPSs use by providing legal frameworks and providing cost subsidies for EPSs implementation. From Table 7.6, a high level of hindrance persists with decreased influences of industry growth-related barriers and financial-related barriers. This further shows the complex nonlinear relationships among the barriers. Thus, tackling industry's developmental needs and providing financial schemes only, does not significantly reduce the resistance EPSs implementation encounter in project implementation.

The findings in this study shows that the five BGs carry dynamic weights in influencing the levels of hindrance to EPSs implementation on construction projects when paired. Aside BG2-BG3, BG3-BG4 and BG4-BG5, paired BGs showed significant sensitivity weights in causing changes in the hindrance composition.

With limited resources to the promotion of EPSs implementation, this study provides a guide in formulating strategies that tackle the barriers to EPSs use. Using the five BGs, thus human-related barriers, technological risk-related barriers, government-related barriers, industry growth-related barriers and financial-related barriers, a decision support system could be developed adopting the nonlinear relationship patterns identified in this study to provide effective selection of strategies. This enables strategies for addressing the barriers to be dynamic regarding specific project environments in Ghana.

7.3 CHAPTER SUMMARY

The slow rate of EPSs uptake for CP processes could be largely attributed to the existence of barriers in project environments and organizations. Specifically, neglecting the inherent grouping effects of barrier interrelations on EPSs adoption poses great danger for understanding the dynamic complexities and influence patterns of barriers. Therefore, this chapter examined the influences of barrier groups in the hinderance levels experienced with EPSs implementation. After data on practitioners' experiences were collected in the survey, descriptive analysis was performed to identify the critical barriers. Out of 21 barriers, 15 barriers were ranked as critical obstacles to the uptake and use of EPSs. For classification of barriers, the factor analysis conducted resulted in five underlying groupings: human-related barriers (BG1); technological risk-related barriers (BG2); government-relation barriers (BG3); industry growth-related barriers (BG4); and financial-related barriers (BG5).

Further, the grouped barriers were adopted into the NFS to learn and predict the composite influences of these BGs. By applying sensitivity analysis to the NFS model developed, several patterns of influences resulting from BGs interrelationships were revealed. For instance, although human-related barriers (BG1) and technological risks related-barriers (BG2) are predominant in literature, tackling BG1 and BG2 alone, exclusively, still presents high levels of hindrances when the remaining BGs are high. With government-related barriers (BG3) and industry growth-related barriers (BG4), addressing their influences to medium levels still offers high levels of obstacles to EPSs implementation. On the contrary, focusing on reducing government-related barriers and financial-related barriers (BG5) has significant gains of lowering the level of hindrance to EPSs. These findings show that the five BGs have non-linear relationships and carry dynamic weights in influencing the levels of hindrance to EPSs implementation on construction projects when paired. Therefore, not all paired BGs have significant sensitivity weights to reduce the hinderance levels to EPSs implementation in projects.

With regard to significant contributions to both knowledge and practice, this study develops a model that shows the nonlinear influence patterns of BGs on the level of hindrance to EPSs implementation, which was lacking in literature. This provides in-depth understanding to the uncertain behavior of BGs. In doing so, the complex interactions between BGs are uncovered for scholars and researchers to clearly understand the influence relationships between BGs and their potential to affect EPSs implementation. This provides insights for researchers to help them contribute to the development of theory with contemporary approaches based on barrier interactions. Also, the application of a neuro-fuzzy system to model the complex relationships among the BGs provides the leverage for researchers to effectively evaluate barriers influences from subjective and uncertain project environments.

From practical perspectives, this study provides a model that is effective and flexible for determining the dynamic influences of BGs to EPSs use within the project environments. More so, decision-makers and project managers in Ghana are offered with the expected level of hindrance considering certain BGs influences in project environments. When the BGs influences are high, decision-makers should identify these BGs and prioritize their influence weights within the total hindrance composition to aid strengthen the efficacy of strategies employed in the current project environment.

CHAPTER 8 ANALYSIS AND RESULTS – EFFECTIVE STRATEGIES PROMOTING EPSs IMPLEMENTATION IN CONSTRUCTIN PROJECTS[10]

8.1 INTRODUCTION

In this chapter, the strategies promoting EPSs implementation and usage in construction projects are presented. Contrary to the barriers that hinder EPSs implementation as elaborated in the previous chapter, the present chapter focuses on examining the synergistic influence levels of strategies promoting EPSs implementation in construction projects. Mean analysis was initially performed after the data was collected to rank the critical strategies promoting EPSs uptake. Further, grouping of the critical factors was conducted using factor analysis and the NFS was used to learn, examine and predict the influence levels of these grouped strategies on promoting EPSs implementation. Additionally, through sensitivity analysis, the convoluted patterns of grouped strategies influences are examined, and optimized approaches are developed for appropriate combination of strategies for effective promotion of EPSs implementation. To this end, several combinations of grouped strategies were explored which informed possible ways of making these grouped strategies effective in various project environments with resource constraints.

[10] This chapter has been fully or partially reported in:
Yevu S. K., Yu A. T. W., Adinyira, E., Darko A., Antwi-Afari, M. F. (Under review). Optimizing the application of strategies promoting electronic procurement systems towards sustainable construction in the building lifecycle: A neurofuzzy model approach. *Journal of Cleaner Production*. Manuscript ID: JCLEPRO-D-20-25572R1
Yu, A. T. W., Yevu, S. K., and Nani, G. (2020). Towards an integration framework for promoting electronic procurement and sustainable procurement in the construction industry: A systematic literature review. *Journal of Cleaner Production*, 250, 119493.

8.2 DATA ANALYSIS AND RESULTS OF STRATEGIES PROMOTING EPSs

Using the Cronbach's alpha for reliability checks, an overall coefficient α value of 0.705 for the 14 strategies identified in this study shows that the internal consistency and reliability of the data collected was high and acceptable. Additionally, data normality check with Shapiro-Wilk (SW) test (*p-values* ≤ 0.05) indicated that the data is not normally distributed (Royston, 1992).

8.2.1 Strategies Promoting EPSs Implementation in Projects

The results of the arithmetic mean analysis for strategies promoting EPSs are summarized in Table 8.1. From Table 8.1, the mean scores indicating the importance of strategies in the promotion of EPSs ranged from 3.12 to 4.52. Normalization computations were conducted and strategies with mean scores not less than 0.50 were identified as critical strategies in the promotion of EPSs in projects.

Out of 14 strategies identified, 13 strategies had normalized values above 0.50 and were therefore deemed as critical strategies in the promotion of EPSs in building projects. The first ranked strategy with the highest mean value of 4.52 was "*organizational leadership buy-in and commitment strategy for EPSs*" (S09) (Table 8.1). This finding shows the prevalence of top management influences in EPSs adoption and further supports past studies indicating the significance of leadership buy-in in the promotion of EPSs in projects (Kang et al., 2012; Lines et al., 2017). The strategy "*incentives and reward schemes for EPSs adoption on projects*" (S02) was ranked second with mean value of 4.45, followed by "*proactive change-management systems*" (S08) with a mean value of 4.45. The fourth ranked strategy was "*EPSs related training programs for key stakeholders*" (S05) having a mean value of 4.29 and the fifth ranked strategy with a mean value of 4.28 was "*availability of quantifiable evidence of EPSs benefits*".

This summary provides the top five critical strategies that are important in the promotion of EPSs in Ghana.

The Kendall's value and significance level for the ranked 14 strategies were 0.188 and 0.000 respectively, indicating substantial level of agreement on the ranking of the strategies from the respondent groups. The Kruskal-Wallis ANOVA test shows that all the strategies had no significant statistical difference (significance > 0.05), except two strategies (i.e. '*pilot implementation projects for contextual learning and knowledge sharing'* (S07) and '*mandatory EPSs policies and regulations'* (S13)). The contractor group had relatively higher rankings for S07 and S13 while the consultant and regulatory agency group had lower rankings for these strategies. One possible explanation is that the contractor group relatively wants more evidence of EPSs benefits and regulations than the consultants and regulatory agency group in the promotion of EPSs in building projects.

Table 8.1 Results of mean analysis for strategies promoting EPS in building projects

Code	All respondents				Consultant			Contractor			Regulatory Agency			Kruskal-Wallis
	Mean	SDv	Normalization[a]	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Test (ANOVA)
S09	4.52	0.684	1.00[b]	1	4.61	0.630	1	4.46	0.508	2[c]	4.37	0.926	3	0.242
S02	4.45	0.670	0.95[b]	2	4.42	0.609	3	4.43	0.573	4	4.52	0.893	1	0.288
S08	4.45	0.806	0.95[b]	3	4.50	0.639	2	4.64	0.621	1	4.11	1.188	7	0.242
S05	4.29	0.676	0.84[b]	4	4.24	0.725	7	4.46	0.508	2[c]	4.22	0.698	6	0.398
S11	4.28	0.635	0.83[b]	5	4.24	0.609	6	4.39	0.629	5[c]	4.26	0.712	5	0.539
S03	4.26	0.639	0.81[b]	6	4.27	0.596	4	4.39	0.629	5[c]	4.07	0.730	8	0.212
S04	4.24	0.671	0.80[b]	7	4.23	0.602	8	4.14	0.705	9	4.37	0.792	2	0.335
S06	4.22	0.652	0.79[b]	8	4.26	0.590	5	4.04	0.693	11	4.33	0.734	4	0.159
S14	4.03	0.774	0.65[b]	9	4.06	0.802	9	4.14	0.705	9	3.85	0.770	10	0.396
S07	3.98	0.841	0.61[b]	10	4.02	0.813	10	4.18	0.819	8	3.67	0.877	12	0.050[d]
S01	3.95	0.669	0.59[b]	11	3.88	0.691	11	4.00	0.385	12	4.07	0.829	9	0.438
S10	3.84	0.876	0.52[b]	12	3.86	0.857	13	3.79	0.876	13	3.85	0.949	11	0.936
S13	3.83	0.843	0.51[b]	13	3.86	0.699	12	4.21	0.833	7	3.33	0.961	13	0.002[d]
S12	3.12	0.808	0.00	14	3.14	0.839	14	2.89	0.737	14	3.30	0.775	14	0.183

Note: SDv = Standard Deviation;

[a]Normalization = (Mean – Minimum Mean) / (Maximum Mean – Minimum Mean);

[b]The normalized value indicates that the barrier is critical (normalized value ≥ 0.50);

[c]Mean values with the same standard deviation;

[d]The Kruskall-Willis test value is significant at the ≤ 0.05 significance level. The Shapiro-Wilk test value for all 14 strategies were ≤ 0.05 significant level. The Kendall's *W* for the 21 strategies was 0.188 with significance level of 0.000.

8.2.1.1 Global perspectives: Ghana, Hong Kong and selected developed economies[11]

From the results of the international survey conducted, as presented in Table 8.2, it is worth noting that organizational leadership buy-in and commitment strategy for EPSs was the only strategy highly ranked in Ghana, Hong Kong and the selected developed economies. This emphasizes the role management support plays in effective EPSs promotion in organizations, irrespective of the socio-economic setting. While reward schemes for EPSs adoption on projects were exclusively ranked high from the Ghanaian perspective, another high ranked strategy – proactive change-management systems, was also ranked high in the Ghanaian perspective and the selected developed economies compared to Hong Kong.

Similarly, as 'EPSs related training programs for key stakeholders' was ranked fourth in Ghana, it was ranked first in Hong Kong as the topmost promotion strategy. The use of educational training programs for EPSs promotion has advantages of convincing and empowering construction stakeholders with EPSs skills, which in turn, might reduce their resistance to its uptake. Although, the availability of quantifiable evidence of EPSs benefits was highly rated in the Ghanaian environment, it had low rankings in Hong Kong and the selected developed economies. Such a strategy is understandable from the developing economies context, since EPSs implementation is infantile, hence, practitioners would require evidence of EPSs benefits before widely employing it in construction projects.

[11] Partially reported in Yevu, S. K., Yu, A. T. W., Nani, G., Darko, A., and Tetteh, M. O. (2021d). Electronic procurement systems in construction procurement: Global experiences of barriers and strategies. *Journal of Construction Engineering and Management*. Manuscript ID: COENG-11130R1(In press)

Table 8.2 Comparison of top 10 strategies promoting EPSs between Ghana, Hong Kong and selected developed economies

Strategies	Ghana		Hong Kong		Selected Developed Economies[a]	
	Mean	Rank	Mean	Rank	Mean	Rank
S09 - Organizational leadership buy-in and commitment strategy for EPSs	4.52	1[b]	4.24	2[b]	4.29	3[b]
S02 - Reward schemes for EPSs adoption on projects	4.45	2[b]	3.94	6	3.69	11
S08 - Proactive change-management systems	4.45	3[b]	3.94	7	4.29	2[b]
S05 - EPSs related training programs for key stakeholders	4.29	4[b]	4.29	1[b]	3.89	6
S11 - Availability of quantifiable evidence of EPSs benefits	4.28	5[b]	3.53	13	3.69	10
S03 - Competent institutional framework and local promotion teams for effective EPSs implementation	4.26	6	3.76	12	3.51	13
S04 - Enable collaborative environment among organizations and partners	4.24	7	3.88	11	3.97	5[b]
S06 - Active and strengthened research and development for EPSs implementation	4.22	8	3.94	8	3.77	8
S14 - Availability of financial support schemes for EPSs investment	4.03	9	3.94	9	3.66	12
S07 - Pilot implementation projects for contextual learning and knowledge sharing	3.98	10	3.88	10	3.74	9

Note: [a] = United States, United Kingdom and Australia.
[b] = EPSs strategies appearing in top five ranks of the selected countries/territories.

8.2.2 Grouping of strategies for EPSs promotion

The underlying dimensions of the 13 critical strategies were grouped into clusters using the FA technique to better understand the complex phenomenon. For appropriateness of the data, the KMO value of 0.693 obtained in this study, is acceptable since it satisfies the minimum threshold of 0.50 (Hair et al., 2009). The Bartlett's test value of 300.378 with an associated significance level of 0.000, indicates that the population correlation is not an identity matrix (Pallant, 2011). Both appropriateness tests demonstrated the suitability of the data for FA. Hence, the principal component analysis was used for factor extraction based on varimax rotation. Variables with factor loadings ≥ 0.50 and components with eigenvalues ≥ 1 were retained due to their significant contribution in the factor group and determining underlying clusters. Five components were extracted which accounted for 65.20% of the variance (acceptable criteria > 50% variance) (Field, 2013) (Table 8.3). This implies that the five component clusters extracted can adequately represent strategies promoting EPSs in construction projects and were subsequently clustered as: (1) technology education (TE); (2) innovation culture management (ICM); (3) technology stimulation environment (TSE); (4) incentives and partnerships mechanism (IPM); and (5) organizational integration support (OIS). These five strategies clusters (SC) serve as input parameters for the neuro-fuzzy model to evaluate their influence and complexity in promoting EPSs in construction projects.

Table 8.3 Clustering of strategies promoting EPSs in building projects

Code Strategies promoting EPSs	Clustered strategies				
	1	2	3	4	5
SC1: Technology education (TE)					
S05 EPSs related training programs for key stakeholders	0.643	-	-	-	-
S06 Active and strengthened research and development for EPSs implementation	0.718	-	-	-	-
S07 Pilot implementation projects for contextual learning and knowledge sharing	0.592	-	-	-	-
S10 Active publicity through media communications	0.652	-	-	-	-
S11 Availability of quantifiable evidence of EPSs benefits	0.645	-	-	-	-
SC2: Innovation culture management (ICM)					
S08 Proactive change-management methods	-	0.733	-	-	-
S09 Organisational leadership buy-in and commitment strategy for EPSs	-	0.797	-	-	-
SC3: Technology stimulation environment (TSE)					
S13 Mandatory EPSs policies and regulations	-	-	0.863	-	-
S14 Availability of financial support schemes for EPSs investment	-	-	0.772	-	-
SC4: Incentives and partnership mechanisms (IPM)	-	-	-	-	-
S02 Reward schemes for EPSs adoption on projects	-	-	-	0.695	-
S04 Enable collaborative environment among organisations and partners	-	-	-	0.818	-
SC5: Organizational integration support (OIS)					
S01 Align EPSs to organisation's strategy and procurement procedures.	-	-	-	-	0.747
S03 Competent institutional framework and local promotion teams for effective EPSs implementation	-	-	-	-	0.646
Eigenvalue	3.110	1.819	1.419	1.131	1.000
Variance (%)	23.923	13.993	10.916	8.703	7.666
Cumulative variance (%)	23.923	37.916	48.832	57.535	65.201

Note: Extraction method = principal component analysis; Rotation method = Varimax with Kaiser normalization

8.2.3 Neuro-Fuzzy System (NFS) Model for the Strategies influences

Fuzzy if-then rules and membership function approximations are generated for input and output variables from the data set. The variable inputs as derived from Table 8.3 for the NFS model are; VI_1 (Technology education), VI_2 (Innovation culture management), VI_3 (Technology stimulation environment), VI_4 (Incentives and partnerships mechanisms) and VI_5

(Organizational integration support). The prioritized mean weight (PMW) was employed in this study to compute the input values of the neuro-fuzzy model. The PMW computes the corresponding weight of a factor within a group based on factor loadings and expert ratings for summation. This enables corresponding weights of factors to be shown in the group. The PMW expresses the importance of VI using Eq. (8.1):

$$PMW_k = \frac{1}{h}\sum_{i=1}^{h} v_{ki} \quad , v_{ki} = w_c d \tag{8.1}$$

where PMW_k is score of kth group of VI_k ($k = 1, 2, \ldots 5$), and v_{ki} is the ith strategy score of the kth VI group, w_c is the coefficient weight of a factor's loading divided by the sum of factor loadings in that group, d is the expert's strategy rating, and h is the number of strategies within the VI.

The VIs were assessed based on three fuzzy rules (low (L), medium (M) and high (H)). The values of VIs were determined from the variables observed and the *PMW* developed. The membership function (MF) determines the fuzzy set which in turn defines each fuzzy value (Rashidi, 2011). The gaussian functions were adopted in this study.

Table 8.4 shows the initial MFs and value parameters. The output variable indicates the impact level of strategies in promoting EPSs. The OV possible values ($f \in \{1, 2, 3, 4, 5\}$), where $\{1, 2, 3, 4, 5\}$ indicates the rating scale for the level of impact in a continuous range from 1 representing low level, through 3 representing medium level to 5 representing high level. The overall number of MFs for the OV is the same number of fuzzy if-then rules created with the fuzzy sets since the first-order Sugeno-type was initially used in the neuro-fuzzy model. The MFs of the OVs are expressed as $f_i = p_i x_1 + q_i x_2 + r_i x_3 + s_i x_4 + t_i x_5 + z_i$, where

$(p_i, q_i, r_i, s_i, t_i, z_i)$ denote the ith fuzzy if-then rule of the consequent parameter set and i represents fuzzy if-then rules. Consequent parameters are initialized based on the output target and the corresponding data pair. Considering the initial values, parameter (z_i) is designated with the output target value and the zero is designated to the remaining parameters. For instance, a data pair with output target of 4 has its initial parameters as {0, 0, 0, 0, 0, 4}.

Concise rules enable the learning process of the networks structure to be reliable, fast and more intuitive (Jin, 2011). Hence, the fuzzy rules created from the numerical input-output dataset was a straightforward approach and reduces the training time in neural networks. Using a three-step procedure, the approach by Wang and Mendel (1992) was employed in this study. The MFs are firstly determined for all fuzzy values relating to each input value of a given data pair. Using example case 1 = (4.45, 4.14, 3.88, 3.57, 4.02 and 4.00), the first five and last values represent input and output values, respectively. The first step calculations are shown in Table 8.4. Secondly, fuzzy values are assigned to each input value corresponding to the maximum membership value of that input. Lastly, one rule is created for each given input-output data pair. Example case 1, the rule is created as:

IF VI_1 = high, and IV_2 = high, and VI_3 = medium, and VI_4 = medium, and VI_5 = high, THEN OV is $f_1 = p_1 \text{x}\, 4.45 + q_1 \text{ x } 4.14 + r_1 \text{ x } 3.88 + s_1 \text{ x } 3.57 + t_1 \text{ x } 4.02 + z_1 = 4$. From this approach, a total of 243 rules were created for the neuro-fuzzy model.

Table 8.4 Fuzzy if-then rule development using example case 1

Variable	Code (Linguistic Value)	Numerical value	Initial MF $\mu(x;\ \sigma, c)$	Membership value (fuzzy value)	Assigned fuzzy value
VI_1	H (High) M (Medium) L (Low)	4.45	$e^{[-(x-5.0)^2]/[2(0.37)^2]}$ $e^{[-(x-4.14)^2]/[2(0.37)^2]}$ $e^{[-(x-3.14)^2]/[2(0.37)^2]}$	0.591(H) 0.355(M) 0.055(L)	High

VI_2	H (High) M (Medium) L (Low)	4.14	$e^{[-(x-5)^2]/[2(0.72)^2]}$ $e^{[-(x-3.23)^2]/[2(0.72)^2]}$ $e^{[-(x-1.47)^2]/[2(0.72)^2]}$	0.936(H) 0.055(M) 0.009(L)	High
VI_3	H (High) M (Medium) L (Low)	3.88	$e^{[-(x-5)^2]/[2(0.53)^2]}$ $e^{[-(x-3.96)^2]/[2(0.53)^2]}$ $e^{[-(x-2.59)^2]/[2(0.53)^2]}$	0.527(H) 0.455(M) 0.018(L)	Medium
VI_4	H (High) M (Medium) L (Low)	3.57	$e^{[-(x-5)^2]/[2(0.42)^2]}$ $e^{[-(x-4.24)^2]/[2(0.42)^2]}$ $e^{[-(x-3.13)^2]/[2(0.42)^2]}$	0.545(H) 0.409(M) 0.045(L)	Medium
VI_5	H (High) M (Medium) L (Low)	4.02	$e^{[-(x-5)^2]/[2(0.39)^2]}$ $e^{[-(x-3.86)^2]/[2(0.39)^2]}$ $e^{[-(x-3.02)^2]/[2(0.39)^2]}$	0.745(H) 0.191(M) 0.064(L)	High

8.2.4 ANFIS Training Model for EPSs Promotion Strategies

To train the model, the dataset was divided into two separate sets: the training dataset and the evaluation dataset. For training purposes, the training dataset was subsequently divided into estimation subset for model selection and testing subset for validating the model. The multi-fold cross-validation technique was employed to partition the training dataset. From the total of 121 datasets gathered in this study, 110 datasets were used for training the model based on 85/15 percent ratio – 85% as estimating subset and 15% as testing subset. For every round of training, a different set of data (15%) was left out for model testing purposes.

Table 8.5 provides summary of the 11 models trained in the ANFIS network architecture in this study with the datasets. The root-mean square error (RMSE) as used in previous studies (Statkic et al., 2020; Akinade and Oyedele, 2019), was used to estimate and validate the models for best performing model selection. The best performing model according to Table 8.5 is model 4 since it has minimum values of mean square error and RMSE. Hence, model 4 is selected for model evaluation.

Table 8.5 Training results of ANFIS models

Neuro-fuzzy model	$MSE_{est.}$	$MSE_{val.}$	$RMSE_{est.}$	$RMSE_{val.}$
Model 1	0.000000020	4.179251287	0.000140659	2.044321718
Model 2	0.000000023	2.617873441	0.000152047	1.617984376
Model 3	0.000000080	1.187227328	0.000282462	1.089599618
Model 4	0.000000019	0.353560378	0.000138735	0.594609433
Model 5	0.007168469	2.081999698	0.084666814	1.442913614
Model 6	0.978492486	2.544078967	0.989187791	1.595016917
Model 7	0.000000072	1.919390059	0.000268809	1.385420535
Model 8	0.000000013	1.697372746	0.000114065	1.302832586
Model 9	0.000000015	0.383727118	0.000120928	0.619457115
Model 10	0.000001086	1.285167876	0.001042278	1.13365245
Model 11	0.000001518	1.233871298	0.001232054	1.110797596

8.2.5 Model Performance Evaluation

The evaluation dataset was used for model performance. The evaluation dataset contains 11 sets of data cases obtained from the total sample obtained in this study. The results of the performance indexes (i.e. RMSE, MPE and MAPE) used for model evaluation are presented in Table 8.6. The values of VIs for each evaluation data pair were entered into the trained NFS, respectively. The model's predicted impact level of strategies was evaluated with the observed impact level of strategies. The results of the evaluation are provided in Table 8.6 and Fig. 8.1.

Table 8.6 Evaluation results of predicted values and observed values

Data case	Observed impact level	Predicted impact level	$E_{eval.}$
1	5	5.4425	-0.4425
2	4	2.9575	1.0425
3	5	4.9999	0.0001
4	5	5.0000	0.0000
5	5	5.0000	0.0000
6	5	3.9998	1.0002
7	5	5.0000	0.0000
8	5	4.8386	0.1614
9	5	4.8933	0.1067
10	5	4.9994	0.0006
11	5	3.8595	1.1405
Model RMSE = 0.573758582			
Model MPE = 5.945681818			
Model MAPE = 7.554772727			

Note: $E_{eval.}$ = Error margin in neuro-fuzzy model evaluation.

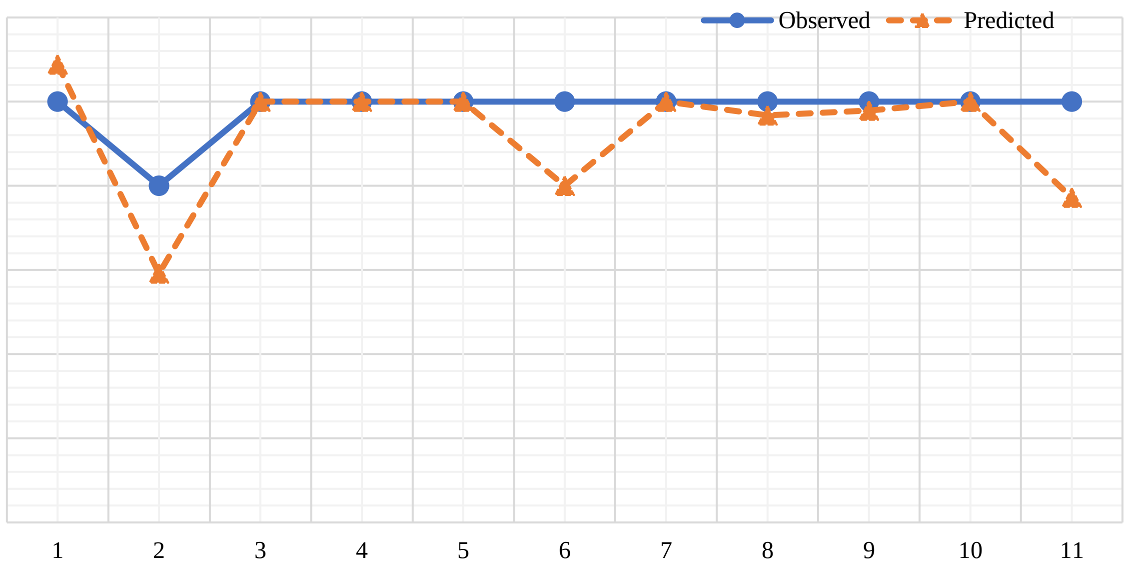

Fig. 8.1 Evaluation of model performance for strategies

The low performance indexes obtained from the evaluation results indicate that the NFS model developed has high capability of estimating the impact level of strategies in the promotion of EPSs. To this end, Table 8.6 shows that about 9 out of 11 (82%) of data cases were accurately predicted by the trained NFS model. The performance indexes suggest that the model may generate an error of 0.574 averagely and may have little over forecasting (+5.95%) which may contain an average error of 7.55% in the forecast. Due to the uncertain and subjective nature of experts' judgements, the model developed with approximately 82% prediction accuracy was deemed adequate to better reveal and predict the complex and nonlinear relationships of strategies impacting the promotion of EPSs in building projects.

8.2.6 Sensitivity analysis for Influences of EPSs strategies

Sensitivity analysis was conducted in this study to assess the impact levels from various SCs influences (Ikram, 2020), considering resource constraints present within project environments. By varying the influence values of specific inputs while the remaining inputs are kept at preferred values (El-Ghohary, 2017), sensitivity analysis provides an approach for identifying ways that optimize strategies for the promotion of EPSs. In determining the influence values of strategies, due to the subjective nature of experts' judgments, the assigned values and MFs ranges from Table 8.4 were employed. This enables subjective and imprecise experiences to be adequately represented using the linguistic expressions characteristic of project environments. The sensitivity analysis was conducted based on project cases (PC) representing typical project environments with limitation in resources for EPSs promotion. A PC depicts a project situation with selected inputs of strategies varied to medium level while the remaining strategies are high. Table 8.7 provides the outcome of the sensitivity analysis, starting from one input variation to three inputs variations successively. Fig. 8.2 shows the scatter plot of PC results from the sensitivity analysis.

Table 8.7 Sensitivity analysis using NFS model

Project Case	Strategies clusters					
	TE	ICM	TSE	IPM	OIS	Output
PC1	M	H	H	H	H	4.7191 (H)
PC2	H	M	H	H	H	4.1035 (H)
PC3	H	H	M	H	H	4.5427 (H)
PC4	H	H	H	M	H	4.4022 (H)
PC5	H	H	H	H	M	4.7413 (H)
PC6	M	M	H	H	H	3.5572 (M)
PC7	M	H	M	H	H	4.8694 (H)
PC8	M	H	H	M	H	3.2813 (M)
PC9	M	H	H	H	M	4.4816 (H)
PC10	H	M	M	H	H	2.0620 (L)
PC11	H	M	H	M	H	3.2342 (M)
PC12	H	M	H	H	M	3.6171(M)
PC13	H	H	M	M	H	4.1101(H)
PC14	H	H	M	H	M	4.5388(H)
PC15	H	H	H	M	M	4.0656(H)
PC16	M	M	M	H	H	1.7881(L)
PC17	M	H	M	M	H	2.2998(L)
PC18	M	H	H	M	M	2.1215(L)
PC19	H	M	M	M	H	1.7419(L)
PC20	H	M	H	M	M	2.1018(L)
PC21	H	H	M	M	M	1.9645(L)

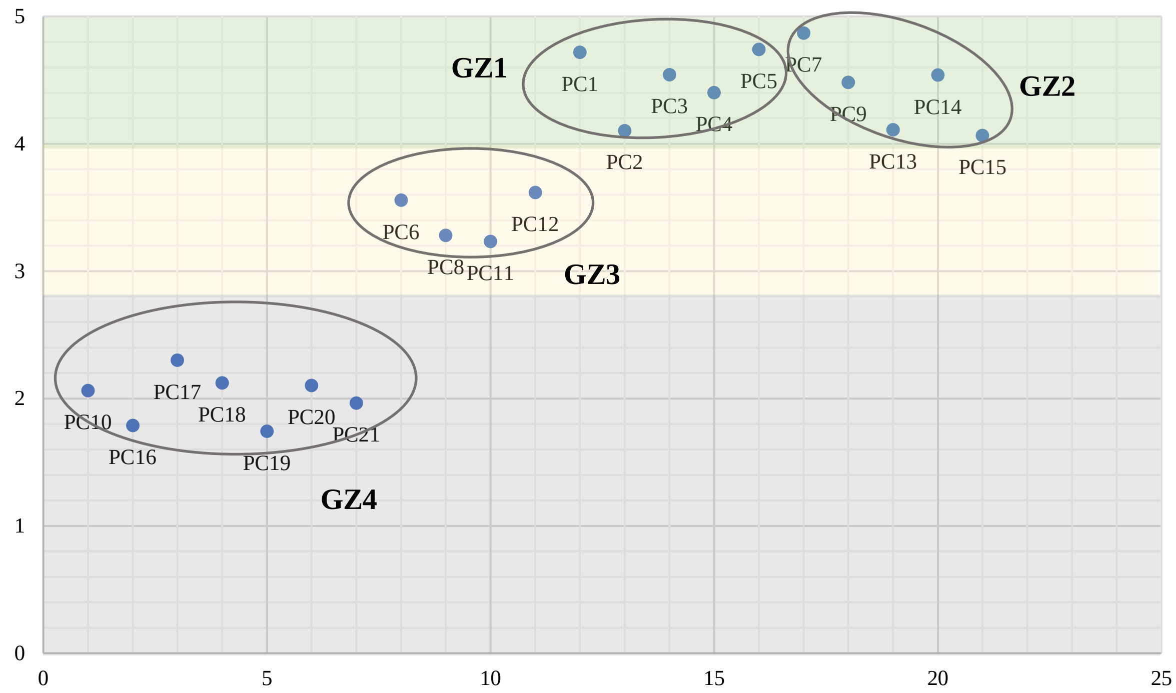

Fig. 8.2 Scatter plot of PC results from sensitivity analysis

From Table 8.7, high impact levels of strategy measures were reported, although specific individual influences of strategies clusters (PC1-PC5) were varied to medium levels. This finding suggests that within the ecosystem of SCs, SCs actively promote EPSs implementation in project environments even though one SC may not have a high influence. This shows that while high levels for innovation culture management have been emphasized in previous studies (Kim et al., 2016; Ozorhon et al., 2016), other SCs can be collectively employed to promote EPSs use. This indicates the existence of complementary relationships in the SCs ecosystem. Fig. 8.2 depicts the impact of these situations (PC1-PC5) in the high-level zone, and was labelled as GZ1. Nevertheless, Table 8.7 shows different impact levels for situations that two SCs (PC6-PC15) were varied. These PCs were subsequently grouped based on their impact levels (GZ2 – high impact and GZ3 – medium impact).

The PCs in GZ2 (i.e. PC7, PC9, PC13, PC14 and PC15) provide a hybrid-approach to achieve high promotion of EPSs with typical resource constraints in construction project environments. For PC7 and PC9, high influences of ICM and IPM combined with OIS or IPM has great capabilities of promoting EPSs in construction projects. This shows that innovation culture can be associated with rewards, collaboration and technological support as a key promotion strategy in the implementation of EPSs. Additionally, associating a stimulating environment for technology through mandatory policies and financial supports to innovation culture and incentive schemes enables EPSs implementation. Alternatively, the hybrid-approach, TE and ICM can be combined with TSE/IPM/OIS as depicted in PC13, PC14 and PC15 (Table 8.7), to facilitate high impact of strategies for the promotion of EPSs implementation (Fig. 8.2). This highlights the synergic influence of technological education and culture (TE-ICM) within the SCs ecosystem, although these two strategies cannot attain high impact alone (see PC21).

Previous studies have independently advocated for increased technological education (Ibem and Laryea, 2015; Kim et al., 2016) and improving innovation culture via proactive change management and leadership support (Altuwaijri and Khorsheed, 2012; Kang et al., 2012). However, this study identified that more will be needed to ensure this approach is effective by enhancing organizational support, incentives and partnerships and a technological environment. Possible explanation for this finding is that organizations with a high innovation culture tend to encourage technological learning, which creates a suitable climate that propels other SCs for optimized results. Also, as earlier indicated, the ICM-IPM approach provides alternative hybrid-approaches for attaining optimized strategies for effective promotion of EPSs implementation.

On the contrary, Table 8.7 also shows that approaches in GZ3 (i.e. PC6, PC8, PC11and PC12) result in medium levels of impact, and hence needs to be critically examined and improved for optimum results. For instance, high TSE and OIS combined with ICM or TE or IPM produced medium impact levels, indicating that the technological environment and organizational support (TSE-OIS) with another SC approach requires improvement for the strategies to be effective. Further, focusing on high TE, TSE and IPM generates medium impact levels, hence may be adequate in actively promoting EPSs. This shows that there are dynamic relationships between the SCs. For example, although high ICM and TE were respectively applied with other SCs in PC8 and PC11, the impact resulted in medium levels. This finding shows some divergence from previous studies, that suggest focusing solely on individual strategies that are deemed important, rather it should be based on careful selection of SCs (Fig. 8.2). To significantly improve the GZ3 approaches (Fig. 8.2), a fourth SC should be increased to high levels, which transforms GZ3 to GZ1. This approach could be used to improve PC10 that has high TE, IPE and OIS, yet the impact is low.

The approaches in GZ4, having three SCs varied, is considered not a suitable approach for the optimization of strategies promoting EPSs implementation in construction projects. This is because all the PCs (i.e. PC16-PC21) resulted in low impact levels (Fig. 8.2). This finding explains the reluctance for EPSs implementation in project environments experiencing passive or average influence of any three SCs concurrently.

The findings in this study show the complex interactions of SCs in determining the impact of strategic measures on promoting EPS implementation. Therefore, the extent of implementation and continued use of EPSs are based on, or affected by, the optimal selection of SCs for effective promotion of EPSs implementation in building projects.

8.2.7 Optimizing the Application of SCs and Implications

The findings of this study have significant implications on practice and theory regarding EPSs use and developments in the construction sector. This research provides practitioners, managers and decision-makers diverse hybrid-approaches to ensure optimized application of strategies for effective EPSs implementation. Considering the need for efficient resource allocation due to constraints and limitation in projects, this study provides knowledge to practitioners for effective application of strategies. Moreover, the findings suggest that combining technological education and innovation culture management with other SCs is a key hybrid-approach with high tendencies of ensuring effective implementation of EPSs. Practitioners and decision-makers would have to refine their efforts through this approach in situations that three of the SCs have to be improved for EPSs use. Alternatively, practitioners can adopt the incentives and partnerships mechanism and innovation culture management with other SCs approach to facilitate EPSs implementation. The findings show that the relationships between the SCs are highly complementary. Hence, for practitioners, this means that SCs have adaptable capabilities with suitable applications in various project situations for optimal promotion of EPSs use. Fig. 8.3 shows the hybrid-approaches of integrating and optimizing the SCs applications for effective EPSs implementation. The bold lines represent hybrid-approaches that have high tendencies of effectively promoting EPSs while the dashed lines represent hybrid-approaches requiring improvements for effective promotion of EPSs implementation.

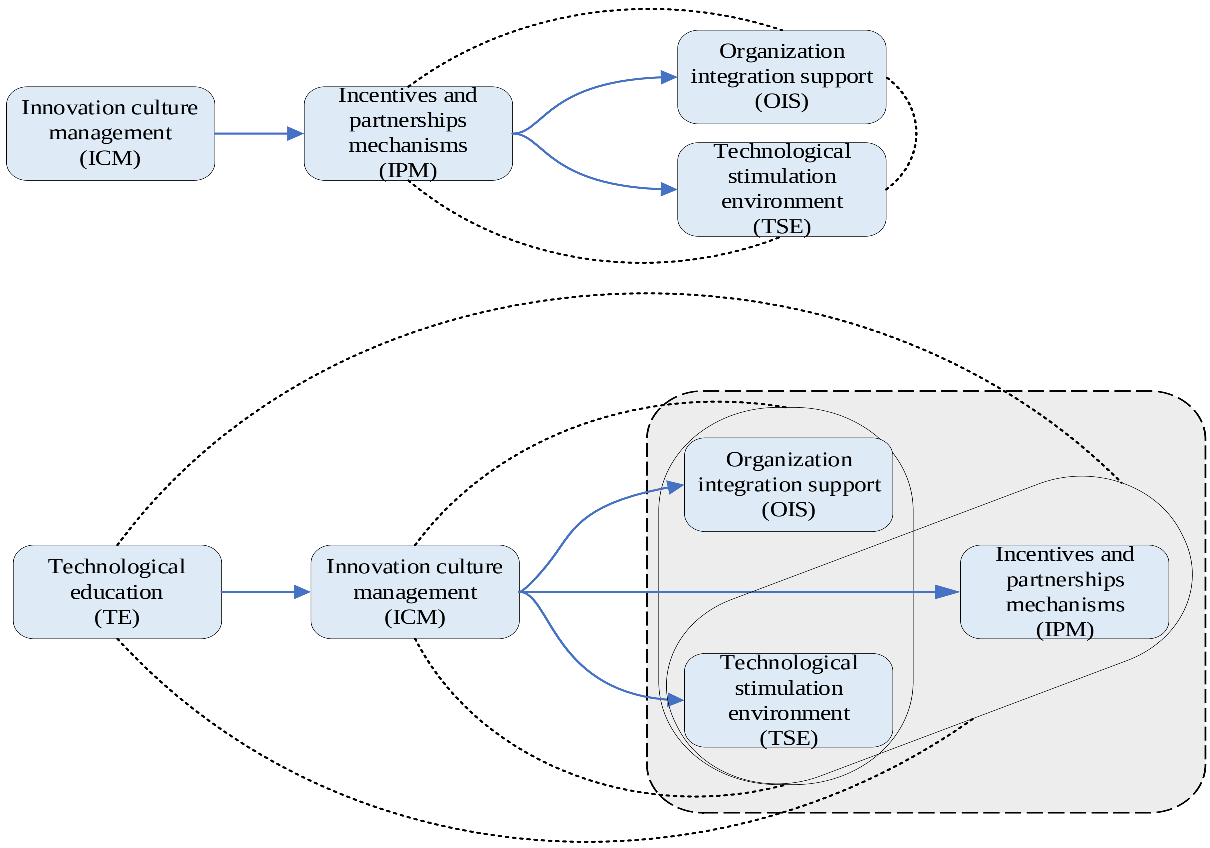

Fig. 8.3 Hybrid-approaches for optimizing strategies

In the developing country context, specifically Ghana, the findings of this study enable the development of integrated strategies that are flexible and adaptive in various project environments. This helps industry practitioners and decision-makers to deepen their understanding in devising targeted strategies for effective promotion of EPSs in construction projects. Government agencies and advocates can use these findings as a guide in decision making to evaluate project environments towards the identification of potential strategies needed for optimizing SCs in the effective implementation of EPS for projects (Fig. 8.3).

Further, this study has significant theorical contributions and implications for EPSs research in the construction sector. This study highlights that there are complex nonlinear interrelationships between the SCs and the co-existence of complementary relationships manifesting in the collective combination of SCs. This provides researchers with deep insights into the dynamic patterns and influences of SCs for further investigation and helps address the issue of limited studies on SCs influences. This study also reveals the diversity of SCs approaches to provide new dimensions on cultural and educational influences in the promotion of EPSs in the construction industry.

8.3 CHAPTER SUMMARY

In improving the use of EPSs in construction projects, strategies that facilitate and promote EPSs uptake in project environments have garnered some attention of industry players. Hence, this chapter analyzed the synergistic influences of clustered strategies in promoting EPSs usage in CP. From the data collected on practitioners experiences with the identified strategies in a survey, the descriptive analysis showed that 13 out the 14 strategies were deemed as critical in promoting EPSs usage. These critical strategies were subsequently clustered using factor analysis into five groups: technology education (TE), innovation culture management (ICM), technology stimulation environment (TSE), incentives and partnerships mechanisms (IPM), and organizational integration support (OIS).

Afterwards, these clustered strategies were employed as variable inputs in the NFS model for prediction of strategies influences. To reveal the influential synergies stemming from the interrelations among strategies, sensitivity analysis was conducted with the NFS developed to assess strategies of various project situations. In project situations that one strategy cluster may have a relatively low influence when the remaining strategy clusters are high, there are high tendencies for the promotion of EPSs in the project environment. This highlights the fact that having a relatively low innovation culture alone while the other strategies are high in the strategies ecosystem, does not deter the promotion of EPSs. Hence decision-makers and practitioners should not be discouraged when faced with similar circumstances regarding the strategies influences. Further, since the strategies are not applied as stand-alone and project environments have typical situations of limited resources, optimized approaches for combining these strategy clusters were developed. Two main paths were identified for combining strategies clusters with other clusters in order achieve effective promotion of EPSs. These two paths are: (1) innovation culture management – incentive and partnerships mechanism; and (2) technological education – innovation culture management. Hence, for practitioners, this means that strategy clusters have adaptable capabilities with suitable applications in various project situations for optimal promotion of EPSs use in construction projects.

Theoretically, the model and the optimized approaches developed enable holistic evaluation and selection of SCs in various project environments for effective promotion of EPSs, as illustrated in the case of Ghana and may be extended as a guide to other countries. The nonlinear pattern of relationships identified in the study helps deepen understanding of SCs dynamic ecosystem, which was lacking in literature. Practically, this study provides knowledge on suitable approaches for optimized application of SCs to ensure effective implementation and continued use of EPSs in building projects for future technological developments.

CHAPTER 9 DEVELOPING AN IMPLEMENTATION SYSTEM MODEL FOR EPSs IN THE CONSTRUCTION INDUSTRY

9.1 INTRODUCTION

Previous chapters, that is, Chapters 6, 7 and 8 analyzed the benefit drivers, barriers and promotion strategies of EPSs respectively, and determined the dynamic complexities and synergistic influences generated by these benefit drivers, barriers and strategies in the implementation process of EPSs in the GCI. This chapter focuses on developing an implementation system model to aid in the promotion and usage of EPSs in CP. In achieving this aim, the findings from the previous chapters were systematically synthesized and incorporated into the implementation process for EPSs considering contextual project environment disparities. Further, this chapter presents the validation of the developed implementation system model to facilitate EPSs implementation in construction projects. The outcomes of this chapter add to the EPSs body of knowledge by improving understanding on the dynamic influences of issues that affect EPSs implementation, and providing a comprehensive guide for policy-makers, project managers and EPSs advocates in determining the suitable project situations for EPSs implementation. Such an understanding is valuable in the EPSs decision-making process by focusing on the areas that are necessary to ensure EPSs usage on projects.

9.2 SYTHESIZING THE SUMMARY OF RESEARCH FINDINGS

To develop the implementation system model, first, the summaries of findings from the benefit drivers, barriers and promotion strategies are compiled separately. This compilation presents the clustering interactions of benefit drivers, barriers and strategies derived from the analysis and serves as the basis for understanding the composition of elements in the implementation system model. Fig. 9.1 presents two aspects of the study, that is, EPSs benefit drivers and the prioritization of quantifiable EPSs benefit drivers. In effect, the critical benefit drivers and their respective groupings, alongside the prioritized benefit drivers for quantitative assessment are mapped in Fig. 9.1, respectively.

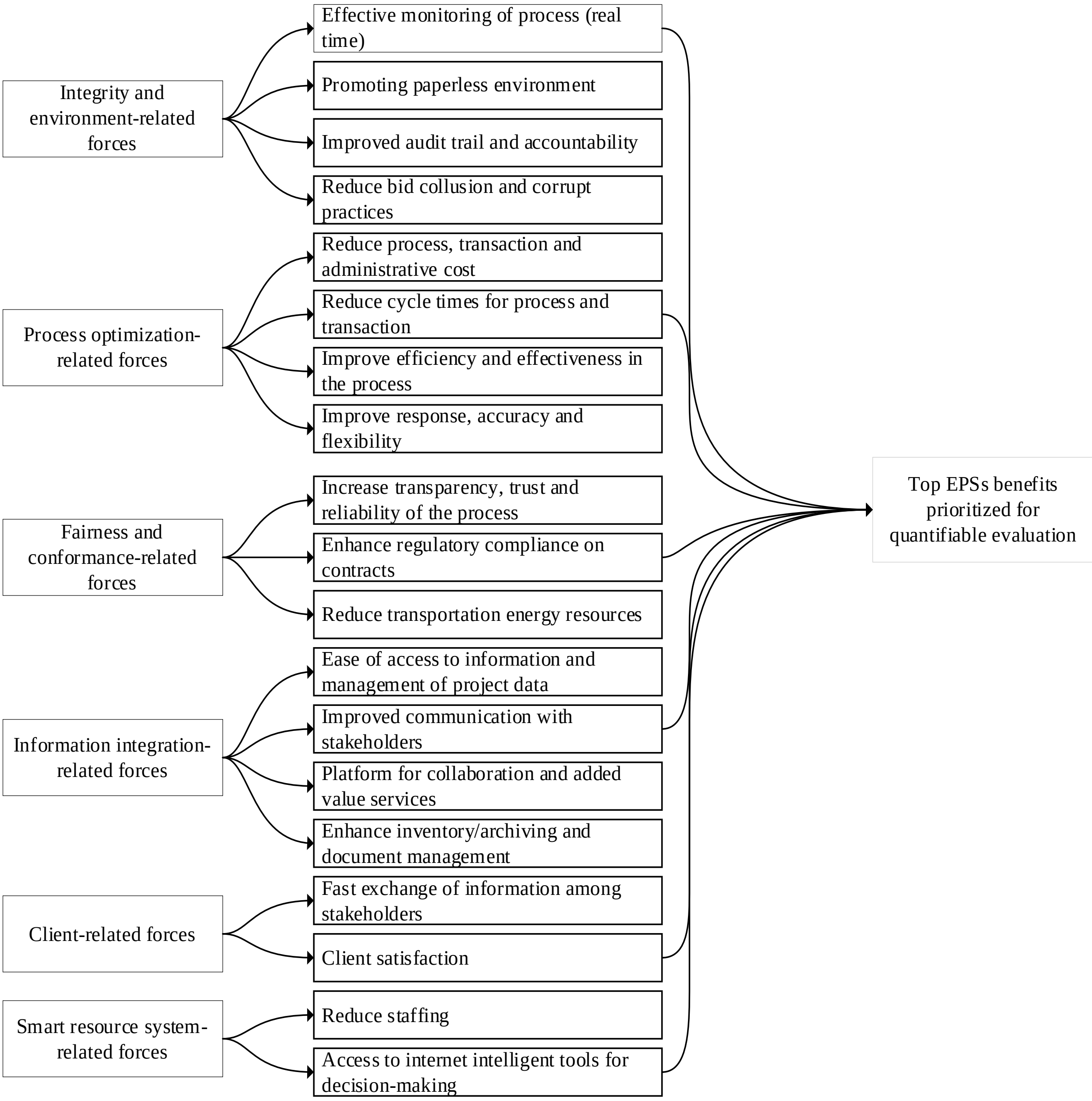

Fig. 9.1 EPSs benefit drivers and their prioritization for quantitative assessment

The interconnections between the groups of barriers are depicted in Fig. 9.2. Further, the connections among barriers in each category are highlighted to indicate the structural configuration of barriers to EPSs implementation in Ghanaian construction projects. Consequently, these interconnectedness provide an indication of the ways in which the barriers obstruct and influence EPSs implementation process.

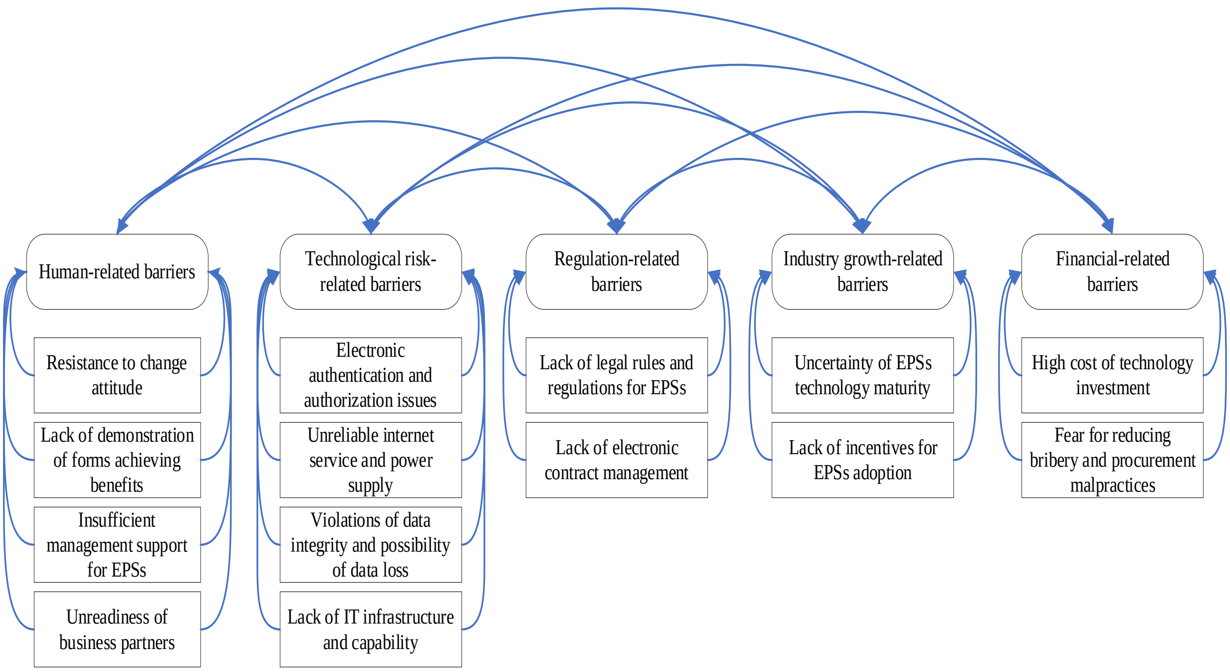

Fig. 9.2 Group structure of barriers to EPSs

Since EPSs strategies are rarely applied as stand-alone in the effort to promote EPSs usage on projects, Fig. 9.3 shows the inherent clustering of strategies promoting EPSs use in project environments. Also, the existence on interrelationships that are crucial in determining the influence of clustered strategies are depicted in Fig. 9.3.

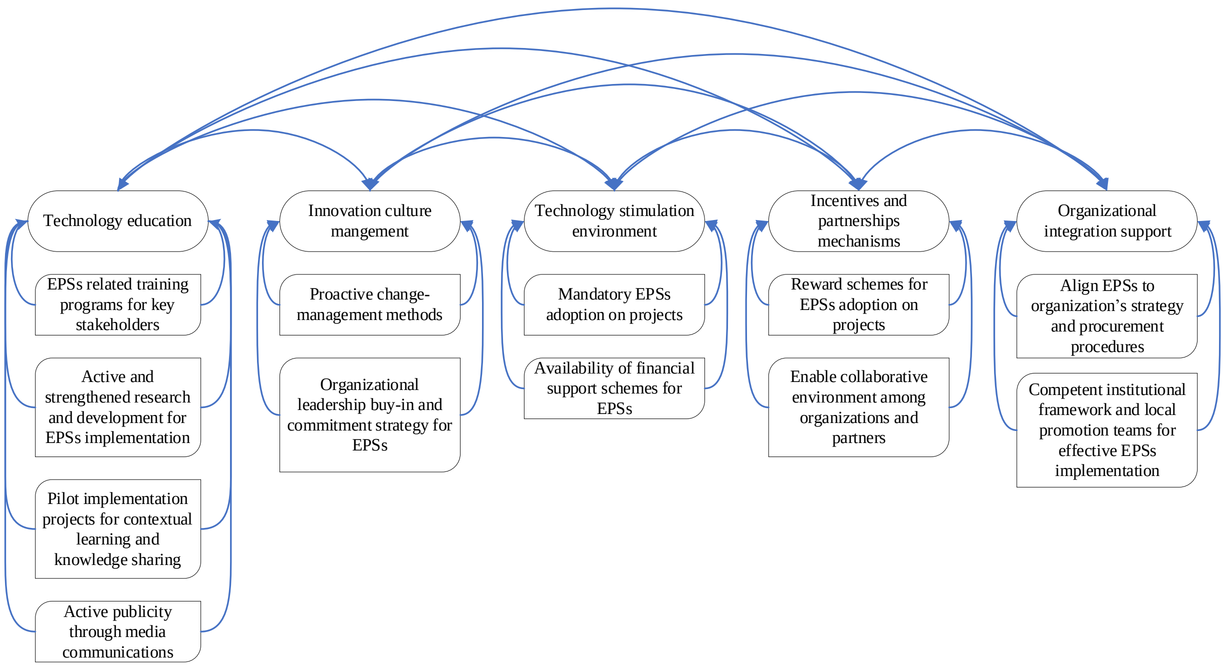

Fig. 9.3 Clustered strategies and interrelationships.

9.2 IMPLEMENTATION SYSTEM MODEL FOR EPSs SUSTAINED UPTAKE IN GHANA

In managing construction projects, project managers and industry practitioners are confronted with various situations in the implementation of EPSs. Inherently, the construction project environment is skewed towards having multi-level stakeholders functioning at various stages of the project, creating uncertainty in CP for EPSs uptake. The interactions of practitioners/organizations interests and the associated circumstances of projects could result in facilitating EPSs uptake or not. Knowledge on such interactions in project environments inform decision-makers on suitable approaches to employ in enhancing EPSs uptakes for CP in construction projects. To this end, an implementation system model was developed with the goal of providing a guide for promoting EPSs uptake in various project environments. The implementation system developed in Fig. 9.4 shows the dynamic complexities of interactions and the project situations that tend to promote EPSs while mitigating the obstacles. The implementation system has two sections – the upper section and the lower section, consisting of EPSs benefit drivers, barriers and strategies in the construction industry.

The upper section of Fig. 9.4 focuses on the creation of a suitable adoption climate with the benefit drivers of EPSs and the preferred benefits for quantifiable evaluation. In stimulating the adoption climate for EPSs uptake, benefit drivers involving integrity and environment, process optimization, fairness and conformance, information integration, client and smart resource system related forces are required among construction practitioners and organizations. These benefit drivers of EPSs motivate practitioners to consider and direct efforts in applying EPSs for CP processes such as tendering. In turn, practitioners' potential level of acceptance for EPSs is improved when these benefit drivers are employed. From the benefit driver categories, individual benefit drivers were prioritized and selected as the preferred representative benefit from the category for quantitative evaluation. These individual EPSs benefits comprised of effective monitoring of process (real time), reduce cycle times for process and transaction, enhance regulatory compliance on contracts, improved communication with stakeholders and access to internet intelligent tools for decision-making. An overview of the individual EPSs benefit drivers suggests that several quantifiable characteristics are required for evaluations. For instance, the quantifiable characteristics for 'client satisfaction' may involve several, but not limited to the quantifiable characteristics required for 'reduce cycle times for process and transaction'. Therefore, a set of quantification characteristics (i.e. percentage of feedback in process, scoring system, average number of units, ratio and time difference) were provided to aid the quantification assessment of EPSs benefits at the implementation and usage stages of projects.

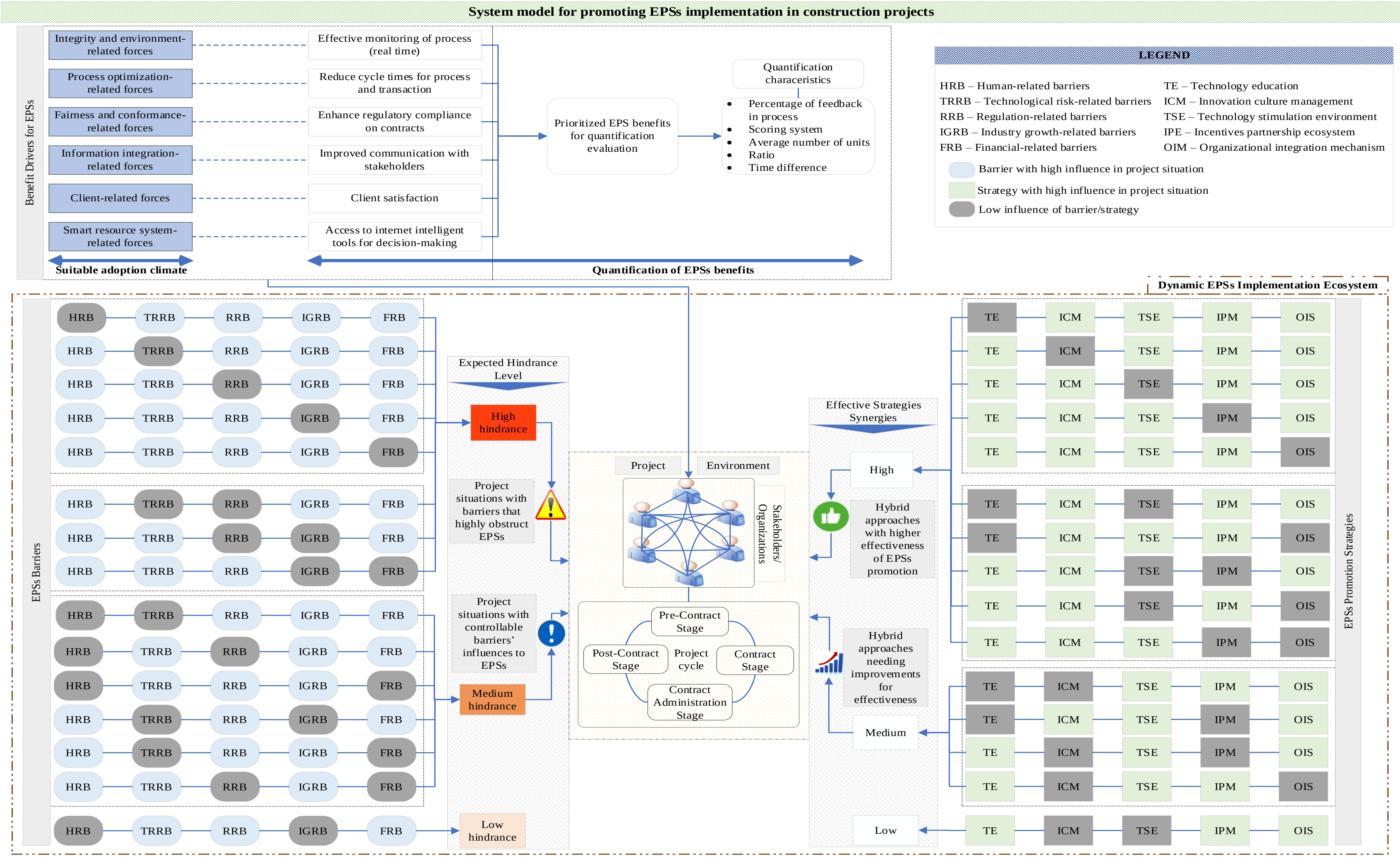

Fig. 9.4 Implementation system model for EPSs uptake in construction project environments

The lower section of Fig. 9.4 presents the dynamic EPSs implementation ecosystem comprising of interactions of barriers and strategies in project environments. Two sub-divisions were created in the lower section of Fig. 9.4, that is, on the left and right side for detailed representation of barriers and strategies respectively. On the left-hand side of the lower section, various project situations containing different influences of barriers (i.e. human-related barriers (HRB), technological risk-related barriers (TRRB), regulation-related barriers (RRB), industry growth-related barriers (IGRB) and financial-related barriers (FRB)) were presented. In a descending order, project situations with high hindrance levels to EPSs implementation were grouped at the top echelon while project situations with medium and low hindrance levels followed afterwards. These project situations represent typical circumstances on projects where one or two barriers may be low and the remaining barriers would be high. As a result, the hindrance levels of these project situations are shown in the "Expected hindrance level" portion. When the hindrance level is high for a project situation, practitioners have to engage active measures to mitigate the influences of barriers for effective EPSs implementation. As the project situations reveal the connected influences of barriers in generating hindrances to EPSs uptake, they further indicate the criticality/severity associated with them which will inform decision-making. Thus, peculiar measures corresponding to these hindrance levels should be adopted to mitigate these barriers in the project environment involving multiple stakeholders and occurring at any stage of the project cycle.

Similarly, the effectiveness of various strategies promoting EPSs in construction projects were presented on the right-hand side in the lower section of Fig. 9.4. Numerous approaches of strategies applications via combinations of the high and low strategies were assessed and the results were calibrated using the high, medium and low effectiveness levels. The effectiveness calibration indicates the synergistic influences of hybrid strategies promoting EPSs in project environments. Such hybrid-approaches inform practitioners of the effect expected when applying these strategies. Consequently, hybrid-approaches with high effectiveness levels offer efficient ways of promoting EPSs in CP while also mitigating the barriers to EPSs that occur in project environments from the project stakeholders and project stages perspectives. Hybrid-approaches with medium effectiveness levels as shown in Fig. 9.4 have to be improved to enhance their EPSs promotion efficacy in project environments. Further, hybrid-approaches resulting in low effectiveness levels must be significantly enhanced by ensuring that the respective strategies with low influences are strengthened to increase their efficacy in EPSs promotion in construction projects.

9.3 VALIDATION OF IMPLEMENTATION SYSTEM MODEL FOR EPSs UPTAKE IN CP

Within the research cycle, validation is the final process with the purpose of testing the credibility, quality, usefulness, and acceptability of research outcomes/models (Hu et al., 2016; Yang et al., 2010). In employing the validation process, it is important to note that the choice of a validation technique is dependent on the specific purpose of the research study (Law, 2007). Hence, there is no established procedure for determining validation techniques and statistical methods to be used in the validation process (Sargent, 2013).

Validation seeks to ensure that the stages in the research methodology are complied with high standards of quality in order to produce outcomes that are credible. In that regard, validation checks usability, practicality, accuracy, reliability, reasonableness and appropriateness of the model (Botten et al., 1989, Fayek, 1998). Accordingly, Lucko and Rojas (2010) highlighted six types of validation in construction engineering management research, namely external validity, internal validity, content validity, construct validity, criterion validity and face validity. Further, the approaches for research validation can be categorized into quantitative and qualitative (Yang et al., 2010). Whereas quantitative approaches involve research design focusing on statistical or objective data with the purpose of testing hypothetical relationships among items such as *t-Test*, qualitative approaches focus on opinion-based data presented in the form of words or ideas instead of numerical data, for example external validity and internal validity (Lucko and Rojas (2010). In this study, the qualitative approach of validation was adopted because the proposed implementation system model and its associated elements are associated with abstract components that are difficult to evaluate quantitatively. Therefore, the collection of opinion-based data was deemed more appropriate as against the other prescribed assessment criteria.

Further, this study developed validation questions focusing on external, internal, construct and content validity in a questionnaire. External validity has to do with the generalizability of the study's outcomes and models (Hu et al., 2016). For this study, external validity examines the generalization capability of the proposed EPSs implementation system model in the GCI. Internal validity focuses on the derivability of relationships within data, hence, causality is its preoccupation (Lucko and Rojas, 2010). It assesses whether the EPSs implementation system model is easily understandable by practitioners in Ghana. Furthermore, the construct validity deals with the operationalization of constructs and assesses whether the research measures what it is supposed to measure (Hu et al., 2016; Lucko and Rojas, 2010). Essentially, construct validity checks the appropriateness and comprehensiveness of the developed implementation system model for the GCI. Lastly, content validity checks whether the study's content correctly represents reality (Lucko and Rojas, 2010). Focusing on this research, content validity assesses whether the EPSs implementation system model developed could ensure EPSs promotion and sustained use in Ghanaian CP, if they are rightfully employed and applied.

9.3.1 Validation survey process

A questionnaire survey was conducted to validate the suitability, practicality, quality and credibility of the proposed implementation system model, in facilitating the sustained usage of EPSs in construction projects in Ghana. While the validation questionnaire was distributed via emails as adopted in Ameyaw (2015), the design of the questionnaire comprised of three sections (see Appendix C). The first section solicited for background information of experts. The second section provided the summary of findings regarding the benefit drivers and their quantifiability, the barriers and strategies promoting EPSs implementation. Conclusively, the comprehensive EPSs implementation system model developed was subsequently presented for evaluation. The third section presented validation statements about the implementation system model for experts to express their level of agreement or disagreement on a five-point rating scale (1= strongly disagree, 2= disagree, 3= natural, 4= agree, and 5 = strongly agree). The experts were purposively selected based the following criteria: (1) expert knowledge and direct involvement in EPSs implementation process and use; and (2) extensive industrial or research experience with EPSs implementation process. Overall, nine experts responded to the validation questionnaire. Table 9.1 shows the background information of expert respondents, which further indicates a diversified group of CP experts at senior levels of management with extensive knowledge and experience in EPSs processes.

Table 9.1 Profile of expert respondents in the validation survey

Expert	Sector	Organization	Position	Industry experience
E1	Public	Consultant	Projects Director	22
E2	Private	Property developer	Director	31
E3	Academic	University/Consultant	Senior Lecturer/Project Consultant	14
E4	Public	Consultant	Contracts Manager	17
E5	Academic	University	Professor	34
E6	Public	Consultant	Contracts Manager	18
E7	Public	Consultant	Procurement Manager	19
E8	Private	Property developer	Project Manager	26
E9	Private	Property developer	Senior Cost Manager/Quantity Surveyor	20

9.3.2 Validation survey results

Table 9.2 shows the results of the validation questionnaire survey. From Table 9.2, it is observed that all the scores for the validation statements were above 4.00. Generally, this implies that the expert respondents agree that all the four validations aspects (i.e. external, internal, construct and content validity) are significantly adequate in the EPSs implementation system model. The external validity of the EPSs implementation system model was examined using statements 1 and 6. Statement 1 had a mean score of 4.67, which means that the significant elements of the EPS implementation system model (i.e. benefit drivers, barriers and strategies) are reasonable and critical within the GCI. Aside that, statement 6 obtained mean scores of 4.33, implying that the EPSs implementation system model developed is highly suitable for facilitating EPSs uptake and sustained usage in CP.

Table 9.2 Results of the validation survey

		Expert responses									
No.	Validation Statements	R1	R2	R3	R4	R5	R6	R7	R8	R9	Mean
1	The significant elements, that is, EPSs benefit drivers, barriers, and strategies identified are reasonable and critical in the GCI.	5	4	5	5	4	4	5	5	5	4.67
2	The EPSs implementation system model is easily understandable and can be used in Ghana.	4	5	4	4	4	3	5	4	4	4.11
3	The guides and steps within the EPSs implementation system model are appropriate.	5	5	4	4	5	5	4	3	4	4.33
4	The EPSs implementation system model is inclusive and comprehensive for all necessary EPSs elements.	4	5	4	4	5	4	4	4	4	4.22
5	The appropriate application of the EPSs implementation system model would successfully help promote EPSs usage in the GCI.	5	4	5	4	5	4	5	4	5	4.56

6	Overall, the EPSs implementation strategy is suitable for promoting EPSs uptake in Ghana.	4	4	4	5	4	4	5	5	4	4.33

Regarding the internal validity assessment, statement 2 obtained a mean score of 4.11, meaning that the EPSs implementation system model is easy to understand and use in the Ghanaian context. Statements 3 and 4 focused on examining construct validity had mean scores of 4.33 and 4.22, respectively. These results first indicate that the guides and steps presented in the EPSs implementation system model are highly appropriate for project application. Also, the results show the inclusiveness and comprehensiveness of the developed EPSs implementation system model is high. Thus, the EPSs implementation system model captures the essential issues of EPSs implementation. Content validity was measured using statement 5, which had a mean score of 4.56. This implies that there are high tendencies for EPSs to be implemented and used on construction projects, if the EPSs implementation system model is properly and appropriately applied in project environments by project managers and policy makers in the GCI. In general, the high mean scores attained for the four validation aspects indicate that the EPSs implementation system model developed is credible, reliable, suitable and effective for promoting the use of EPSs in CP in the Ghanaian context.

9.4 CHAPTER SUMMARY

Within EPSs implementation process, various benefit drivers, barriers and promotion strategies influence project organizations' efforts, actions and decisions in adopting EPSs in CP. This chapter presented a comprehensive EPSs implementation system model that captures the significant benefit drivers, with the influential barriers and the effective strategies in the implementation of EPSs in various project environments. The implementation system model was developed based on consolidated findings from previous chapters to reveal the dynamics of influential issues affecting EPSs implementation. Subsequently, the implementation system model was validated with nine experts. The validation results showed the developed implementation system model is generally suitable, reasonable, applicable and practical promoting EPSs uptake and use in CP. Therefore, by carefully following the guides and steps in the implementation system models, construction practitioners, policy-makers and project managers would ensure success in EPSs implementation processes in the GCI.

CHAPTER 10 CONCLUSIONS AND RECOMMENDATIONS

10.1 INTRODUCTION

The preceding chapters present various processes and aspects of the research study. While Chapter 1 introduces the overall research study, Chapter 2 describes the research methodology and Chapters 3, 4 and 5 offer discussions in literature on various issues. Chapters 6, 7 and 8 report on the empirical research of various aspects of the study and Chapter 9 offers the development of an implementation system model. The present chapter summaries how these objectives have been addressed in this research study and presents the conclusions on various aspects of the study. Further, the chapter explains the theoretical and practical implications of the research. Additionally, the contributions, significance and the added value of this research to construction procurement-related domains are presented in this chapter. Lastly, this chapter presents the limitations of the research study and provides recommendations for future research.

10.2 REVIEW OF RESEARCH OBJECTIVES AND CONCLUSIONS

The overall aim of this research study was to develop a model for promoting the use of EPSs for CP processes/activities in the GCI. To achieve this aim, the following objectives were formulated:

1. To identify the important EPSs benefit drivers and to examine the influences of the benefit drivers in EPSs adoption process in Ghana.
2. To identify quantifiable EPSs benefit drivers for evaluation in Ghana.
3. To identify the critical barriers to EPSs implementation in construction procurement and model their influential relationship patterns on EPSs uptake in Ghana.

4. To identify the important strategies for EPSs implementation and evaluate their synergistic influences in the promotion of EPSs implementation in Ghana.
5. To develop an implementation model based on the results of this study, to aid in the promotion and implementation of EPSs in the construction industry in Ghana.

A wide array of research methods were employed in attaining the objectives of this study (see Chapter 2). Although, the study's findings are presented in previous chapters, the subsections below highlight and summarize the major findings and conclusions regarding each research objective in the study.

Objective 1: To identify the important EPSs benefit drivers and to examine the influences of the benefit drivers in EPSs adoption process in Ghana

A comprehensive review of literature on the drivers and benefits motivating the adoption and use of EPSs in construction projects was conducted in Chapter 4. Consequently, 26 benefit drivers were identified from extant literature on EPSs and were adopted in a questionnaire survey involving procurement practitioners with experience in EPSs implementation processes. In Chapter 6, the results indicate that 19 benefit drivers were significant, with the top five benefit drivers being: (1) reduce cycle times for process and transaction; (2) reduce process, transaction and administrative cost; (3) improved audit trail and accountability; (4) increase transparency, trust and reliability of the process; and (5) promoting paperless environment. By employing factor analysis via principal component analysis on the significant benefit drivers, six PDFs were identified, thus; (1) integrity and environment-related forces, (2) process optimization-related forces, (3) fairness and conformance-related forces, (4) information integration-related forces, (5) client-related forces and (6) smart resource system-related forces.

This grouping was essential as it facilitated the derivation of a smaller set of driving forces needed for further examination and understanding the benefit drivers of EPSs.

Furthermore, in Chapter 6, the FSE technique was applied to examine and model the influence impact of these grouped benefit drivers on EPSs adoption in CP. The results showed that the overall influence level of the six PDFs was 4.20, indicating that, collectively, the grouped benefit drivers of EPSs are very influential, and if well combined, have high tendencies of motivating EPSs uptake in construction project environments. Although, all the PDFs obtained high influence levels in the model, the most critical driving force was integrity and environment-related forces, followed by process optimization-related forces. The outcomes of the developed benefit drivers fuzzy model could serve as means by which practitioners determine the potential EPSs acceptance levels and also optimize the tendencies of achieving high acceptance of EPSs. The model outcomes would be of great value for researchers, project managers, procurement professionals and policy makers to understand influential areas that require strengthening and improvements in creating a suitable project environment that stimulates EPSs adoption in Ghana.

Objective 2: To identify quantifiable EPSs benefit drivers for evaluation in Ghana

EPSs benefits that are quantifiable for evaluation were discussed in the literature review (Chapter 4). A further investigation was conducted on the benefit drivers groupings derived from the analysis. The 19 benefit drivers and the six groupings formed the basis for the application of the AHP technique and enhanced the conceptual development of an EPSs benefit model for quantifiability based on comparisons. Priority weights were established for EPSs benefits within each EPSs benefit category using the AHP comparison weightings (see Chapter

6). Based on the results, the conceptual AHP model was revised and the final model was presented indicating the benefits prioritized for quantifiable evaluation. In order of preference, the EPS benefits categories and their respective individual benefits prioritized for quantification are described as follows: (1) Integrity and environment category – Effective monitoring of process (real time); (2) Process optimization category – Reduce cycle times for process and transaction; (3) Fairness and conformance – Enhance regulatory compliance on contracts; (4) Information integration category – Improved communication with stakeholders; (5) Client category – Client satisfaction; and (6) Smart resource system – Access to internet intelligent tools for decision-making. The outcomes of these comparisons support industry practitioners and procurement professionals responsible for decision-making in the GCI to identify and select the most representative EPSs benefits that are preferred for quantification, towards the realization of EPSs benefits in the implementation and usage process. Such prioritizations enhance efficient and effective use of resources expended for benefit realization regarding EPSs in the CP by construction project organizations. Furthermore, researchers and scholars are provided with a comprehensive list of EPSs benefits that inform which benefits should be investigated for ways of quantification in construction projects.

Objective 3: To identify the critical barriers to EPSs implementation in construction procurement and model their influential relationship patterns on EPSs uptake in Ghana

Through a systematic review conducted in Chapter 5, 21 barriers to EPSs implementation were identified from existing literature and were subsequently adopted in a survey. In Chapter 7, the results of the questionnaire survey showed that 15 barriers were critical in the adoption of EPSs in CP. The top five barriers were; (1) resistance to change attitude, (2) unreliable internet service and power supply, (3) lack of IT infrastructure and capability, (4) insufficient management support for EPSs, and (5) unreadiness of business partners. Factor analysis was carried out on the 15 critical barriers to establish the underlying barrier groups to EPSs adoption. Five underlying groups of barriers were deduced; (1) human-related barriers; (2) technological risk-related barriers; (3) government-related barriers; (4) industry growth-related barriers; and (5) financial-related barriers. More importantly, the barrier groups facilitated the application of the NFS model by serving as input parameters for the barriers model.

The NFS model, in tandem with sensitivity analysis, was then applied to examine and model the influence patterns of barrier groups to the implementation process of EPSs (see Chapter 7). The results from the NFS model showed various patterns in which the barrier groups influence EPSs uptake, with addressing human-related barriers and technological risk-related barriers/government-related barriers being a major pattern of reducing the hindrance level to EPSs implementation. The outputs from the barriers NFS model provide project managers and policy-makers with an effective and flexible model in determining the dynamic influences of barriers in various construction environments, by offering the expected level of hindrances which equip project managers with knowledge of barriers influence behaviors. Further, the NFS model's outcomes would be useful to industry organizations interested in promoting EPSs in Ghana, since different project environments present different barriers to EPSs.

Objective 4: To determine the important strategies for EPSs implementation and evaluate their synergistic influences in the promotion of EPSs implementation in Ghana

In identifying the strategies that ensure EPSs implementation on projects, a comprehensive review of literature was conducted in Chapter 5. The review process identified 14 strategies that promote EPSs in projects. Thereafter, through a survey, procurement professionals in

Ghana evaluated the relative importance of these strategies. The results presented in Chapter 8 indicated that 13 strategies were important, with the top five strategies listed as: (1) organizational leadership buy-in and commitment strategy for EPSs; (2) incentives and reward schemes for EPSs adoption on projects; (3) proactive change-management systems; (4) EPSs related training programs for key stakeholders; and (5) availability of quantifiable evidence of EPSs benefits. Since the strategies are typically not applied as stand-alone in the promotion of EPSs, the strategies were clustered using factor analysis to reveal the underlying strategies (Chapter 8). Five underlying clusters of strategies were derived from the factor analysis results: (1) technology education; (2) innovation culture management; (3) technology stimulation environment; (4) incentives and partnerships mechanism; and (5) organizational integration support. Subsequently, the clusters of strategies were used as input parameters for the NFS model.

While the NFS model was applied to the strategies clusters to examine and predict their influences in the promotion of EPSs, sensitivity analysis was adopted to model hybrid approaches with their level of effectiveness and how their application could be optimized in project situations. The results from the NFS model showed that combining technological education-strategy and innovation culture management-strategy with other strategies clusters is a key hybrid-approach with high tendencies of ensuring effective implementation of EPSs. Nonetheless, fusing incentives and partnerships mechanism strategy and innovation culture management strategy with other strategies clusters present an approach that significantly facilitate EPSs implementation on projects. In addition, ways through which the effectiveness of some hybrid-approaches can be optimized are shown in the results. The outcomes of the strategies NFS model is of immense value to practitioners and policy-makers as they enhance the development of integrated strategies that are flexible, adaptive and effective in various project environments. Furthermore, project managers, procurement professions and researchers are guided in the selection of strategies to apply for an effective and widespread implementation of EPSs in the construction industry.

Objective 5: To develop an implementation model based on the results of this study, to aid in the promotion and implementation of EPSs in the construction industry in Ghana

Based on the results from the fuzzy evaluation of EPSs benefit drivers (Chapter 6) and NFS models for barriers and strategies (Chapter 7 and 8), respectively, a consolidated implementation system model to promote EPSs in Ghana was developed in Chapter 9. The implementation system model comprises of two sections – an upper section and a lower section. The upper section entails EPSs benefit drivers alongside EPSs benefits prioritized for quantifiable evaluation, while the lower section contained the barriers to and the promotion strategies for EPS uptake in CP, in addition to the dynamics of contextual project environments and stakeholders. Further, the implementation system model was validated with nine experts comprising of industry practitioners and academics. The validation results demonstrated the comprehensiveness, credibility, reliability and practicality of the implementation system model for promoting the widespread uptake of EPSs in the GCI.

10.3 RESEARCH CONTRIBUTIONS AND SIGNIFICANCE OF STUDY

The findings of this research presented in the previous chapters present an avenue for essential recommendations to be prescribed for project managers, procurement professionals and decision-makers in their efforts to implement EPSs widely in Ghana. Although, the significance, value and contributions of this study to the respective research objectives have been previously provided, to avoid needless repetitions, and yet not neglecting significant implications, this study briefly summarizes and where necessary, explicates the value and significance of this research. This study makes significant contributions to EPSs body of knowledge and to industrial practice on the implementation and sustained usage of EPSs in CP, especially for developing economies. Furthermore, the research findings offer impactful and valuable implications for promoting widespread uptake of EPSs in Ghana, and could be extended to enrich global practices for EPSs adoption in the construction industry.

First, for the study's contribution and value to EPSs body of knowledge, this study established the important benefits, barriers and strategies pertaining to EPSs uptake, hence, providing useful insights on what to look out for when considering EPSs implementation in Ghana. This offers valuable basis for researchers to further explore variations in the importance of benefits, barriers and strategies not only in the context of the GCI, but also with other construction industries as well.

Second, the findings from the modelling of EPSs benefit drivers, barriers and strategies within Ghana, does not only address the critical gaps in EPSs body of knowledge on the synergistic and clustered effects, but also tackle the influences of these issues in contextual project environments. Specifically, the composite influences of EPSs benefit drivers for creating suitable climates for EPSs acceptance are provided. Further, the findings on the complex non-linear influence interrelationships among the barriers and strategies, offer invaluable education and intelligence for researchers, academics, policy makers, regulatory agencies and industry practitioners on the dynamics involved when promoting EPSs uptake in different project situations. Such insights enrich the knowledge area that was lacking in EPSs literature by providing understanding on the contextual behavior of barriers and strategies. In that regard, this study reveals how the relationships among the clustered barriers and strategies influence EPSs adoption in the construction industry.

Third, the study's use of fuzzy evaluation model for the benefit drivers and the NFS model for the barriers and strategies provide opportunities of assessing uncertain and imprecise projects circumstances, which typically shrouds construction technology adoption, especially EPSs in developing economies like Ghana. This affords construction technology adoption researchers with an effective approach to evaluate the related constructs of EPSs in other economies/territories.

Lastly, the identification of EPSs benefit drivers preferred for quantitative assessment from the benefit driver categories in Ghana, ignites scholarly debate on benefit evaluation in two dimensions – how and when the EPSs benefits would be evaluated in the implementation process and which indicators/characteristics would be suitable, efficient and effective in measuring these benefits for quantitative evaluation. Although, this study solves the question of 'which' or 'what' EPSs benefits are required for quantifiable evaluation in Ghana, it is also beneficial for researchers and practitioners interested in providing quantifiable evidence of EPSs in Ghana.

For industrial practice, the findings and outcomes of this research has several implications for decision and policy making in Ghana and other developing economies. Incipiently, the establishment of key EPSs benefit drivers, barriers and strategies resulting in the development of an implementation system model in this research, has high influence to bring about policy developments towards EPSs uptake and use in Ghana. Because these findings have extensive implications on organizational and industrial systems. Specifically, the significant benefit drivers of EPSs enhance practitioners' understanding on what to focus on in the creation of a stimulating project environment should it be needed for EPSs uptake in Ghana. In effect, practitioners would be able to learn and conduct better forecasting regarding EPSs acceptability among project or stakeholder organizations. From the practitioners' perspective, such insights serve two purposes in improving decision-making, that is, knowing the essential areas to strengthen in order to motivate project stakeholders, and whether to continue investing in EPSs or suspend the implementation process if the project environment is not suitable. Therefore, practitioners are encouraged to carefully monitor the adoption climate for EPSs acceptability.

In addition, the study's findings on the complex influence patterns of barriers to EPSs implementation in Ghana, enable procurement practitioners and project managers to anticipate the levels of hindrance to be experienced in their respective project situations. Therefore, decision-makers in the implementation process of EPSs are informed to be proactive in selecting the barriers to tackle within uncertain project environments in Ghana. Typically, project organizations (public or private) interested in EPSs are equipped with knowledge that shapes their objective assessment of potential hindrances when implementing EPSs tools (e.g. e-tendering) among construction stakeholders.

More importantly, the research outcomes on the strategies promoting EPSs uptake and use in construction projects are of great value to procurement professionals and practitioners in two directions – guide for selecting important strategies and for efficient resource allocation in promoting EPSs in Ghana. As a guide, the identification of important strategies, along with their synergistic interactions influences enable industry practitioners and procurement managers of public and private agencies to know which strategies are highly effective when applied. The added value of this finding in the study, lies in the identification of effective hybrid-approaches and ways of optimizing some hybrid-approaches to increase their effectiveness for EPSs promotion. Consequently, industry practitioners are guided as to how to integrate these promotion strategies to facilitate EPSs uptake. Since the resources on projects are limited for construction organizations in Ghana, this research offers regulatory agencies and practitioners approaches that enable efficient resource allocation in the promotion of EPSs in various project situations. In applying these strategies, decision-makers and practitioners are encouraged to first assess the strategies that are dominant and available within the project domain before integrating the strategies using the hybrid-approach.

Finally, the implementation system model developed provides a guiding mechanism for practitioners to accelerate EPSs uptake in the GCI. First, the implementation system model elucidates procurement practitioners on how to systematically assess project environments for suitable EPSs implementation. Second, the guides and steps developed in the implementation system model galvanizes policy developments towards the increased use of EPSs in CP in Ghana, because this study’s findings have wider implications involving legal frameworks, education and financing for existing industrial and organizational structures. Besides, where the experiential knowledge on the influences of these issues on the implementation process of EPSs is lacking, the implementation system model provides the needed guiding frame for industry practitioners and professionals in decision-making. Overall, this study is very important for Ghana and useful for other developing economies, since Ghana as much as other several developing economies, are presently at infantile stages in the widespread adoption of EPSs in their respective construction industries. More so, this study is important for the promotion of digitalization in the construction industry, and for achieving efficient use of resources towards construction technology adoption. In effect, economic and environmental gains would be attained in the promotion of EPS implementation in the construction industry.

10.4 LIMITATIONS OF THE RESEARCH STUDY

Analogous to any research study, the present study has some limitations that are worth mentioning despite its achievement of the research aim and objectives. First, due to EPSs developments being at nascent stages in Ghana, the research survey was based on a relatively small sample size of procurement practitioners with experiences in EPSs implementation process. Second, the evaluations made in this research were generally considered subjective, since these evaluations might be influenced by respondents' backgrounds and experiences. Thus, composition of experts in this research should be carefully considered when extending the findings of this study to other construction industries, especially industries with different composition of practitioners. In addition, this research focused on EPSs uptake in construction projects in Ghana, and hence presents limitations concerning generalizations due to contextual differences in the characteristics of other construction industries globally. Generally, this study involved various types of projects, therefore, in-depth details pertaining to specific projects and EPSs uptake were limited. Finally, although the potential of the implementation system model developed which is based on industry experts' knowledge has been validated for its comprehensiveness, reliability, practicality and reasonableness, there is more room for testing in real project environments to consolidate and improve the implementation system model outputs.

10.5 RECOMMENDATIONS FOR FUTURE RESEARCH

Notwithstanding the study's usefulness to researchers and practitioners in the promotion and use of EPSs in construction projects, there are still opportunities for future research to strengthen and improve EPSs implementation in the construction industry:

First, since the EPSs implementation system model developed in this research was based on current conditions of significant issues associated to EPSs uptake in Ghana, there may be some changes over time as EPSs practice increases from its embryonic stages in the GCI. Therefore, it would be valuable for future research to follow the methodology of this research to refine, improve and consolidate the implementation system model for practice.

Second, as this study mainly focused on one developing economy – Ghana, it would be essential for future research to focus on other developing economies and regions (e.g. South-East Asia) to further enhance the generalizability of the study's findings and implications. This is necessary, as different countries may have different regulations and conditions within their construction industries. This promotes comparative research among developing economies which could establish the study's findings in the broader context of developing economies in the South-East Asia region.

Third, researchers are encouraged to engage larger sample sizes in the future as EPSs practices increases in the GCI. This would help enhance the inclusion of multidimensional perspectives on the implementation EPSs for a sustained usage in project environments.

Fourth, the study's findings on the synergistic influences of barriers and strategies present a starting point for future research to explore the structural dynamics of how these barriers and strategies interrelate on construction project towards the promotion of EPSs.

Fifth, future research could develop and establish intelligent support systems for decision-making (ISS-DM), building on the implementation system model by employing advanced techniques such as big data analytics and artificial intelligent tools, e.g. machine learning. The creation of a database for collective information of EPSs implementation issues on various construction projects, would enable researchers and practitioners to identify and analyze patterns of EPSs developments at both the broader and the specific levels.

Lastly, to enhance EPSs uptake amidst the current construction digitalization agenda, i.e. blockchain and internet of things (IoT) in *'Industry 4.0'*, future research must consider integrating emerging technologies associated with procurement into EPSs operational processes for CP. This would help improve the currency of EPSs in solving CP problems in the future. Consequently, future research should increase their interest in the sustainability contributions of EPSs in construction industries.

10.6 CHAPTER SUMMARY

This chapter presented the major conclusions from the five objectives of this research. Additionally, the contributions and significance of the research are summarized, followed by limitations. More importantly, recommendations for future research in EPSs implementation and use in Ghana and other regions were outlined in this research.

APPENDICES

APPENDIX A

GENERAL SURVEY QUESTIONNAIRE

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

DEPARTMENT OF
BUILDING & REAL ESTATE
建築及房地產學系

Dear Sir/Madam

Invitation to participate in a Doctor of Philosophy (PhD) research into promoting electronic procurement adoption for construction procurement in Ghana

As a practitioner with knowledge in e-procurement or e-tendering in Ghana, you are cordially invited to complete the attached questionnaire for a PhD research entitled **"Promotion of Electronic Procurement Adoption in Ghana: Model Development for the Influential Issues."** This research is sponsored by The Hong Kong Polytechnic University's Postgraduate Studentship Scholarship, and under the supervision of Associate Professor Ann T. W. Yu. The research seeks to identify and evaluate the influential issues associated with the adoption and implementation of e-procurement and also provide insights into critical strategies needed for promoting e-procurement in Ghana. Analytical models of the critical issues based on the research findings will be developed to accelerate the widespread adoption of e-procurement for construction procurement in Ghana. It is envisioned that this study will potentially contribute to national and industrial strategies focused towards efficiency and effectiveness for sustainable development in the country.

The questionnaire survey is a general survey which aims at soliciting the perspectives and experiences of procurement experts on the attributes related to the adoption of electronic procurement (e-procurement) in the construction industry. The questionnaire is simple and takes approximately 20 minutes to complete. **There are no wrong or correct answers, only your much-needed opinions.** All your responses will be treated with strict confidentiality and used only for academic purpose.

We understand that this survey will consume some of your precious time, but this research will not be successful without your expert opinions. **Lastly, we would be grateful if you can forward the questionnaire to other experts, who you know have rich experience or knowledge of the topic.** Many thanks for your kind consideration.

For any enquiries, please contact;
Sitsofe Kwame Yevu (Tel.: +8529296 /+23324370 ; and email: sitsofe-k.yevu@)
or
Associate Professor Ann T. W. Yu (email: bsannyu@).

Your views are very vital for the success of this research. After the research, we are willing to share summary of the outcomes with practitioners in the country and anyone who shows interest.

We would be grateful if you could complete and return the questionnaire to the researchers within **two weeks**. Thank you once again for your kind consideration.

Yours sincerely,

…………………………….

Sitsofe K. Yevu, PhD Candidate
Associate Professor Ann T. W. Yu, Department of Building and Real Estate
The Hong Kong Polytechnic University
Hong Kong

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

DEPARTMENT OF BUILDING & REAL ESTATE
建築及房地產學系

Promotion of Electronic Procurement Adoption in Ghana: Model Development for the Influential Issues

Questionnaire Survey

Important instructions:

1. Please consider your experience in the Ghanaian construction industry to complete this survey.
2. Note that for simplicity, **"e-procurement"** is used in the questionnaire to denote **"electronic procurement".**
3. Use any suitable symbol (such as "√") to indicate your opinions.
4. Please you have **TWO WEEKS** to complete the questionnaire.
5. Your mobile number: ________________________and email address: ___________________________
6. For any queries, please contact me on Tel.: 024370 or e-mail: sitsofe-k.yevu@ .

Section A: Information of Participant

Q1. What type of organization do you work for?

Consultant☐; Contractor☐; Regulatory Authority☐; Others(s) (please specify): ___________

Q2. What is your professional background?

Project manager☐; Engineer☐; Quantity Survey☐; Architect☐; Other(s) (please specify): ___________

Q3. What is the number of your working experience in the construction industry?

1-5yrs☐; 6-10yrs☐; 11-15yrs☐; 16-20yrs☐; Over 20yrs☐

Q4. Your years of experience in e-procurement for projects.

1-3yrs☐; 4-6yrs☐; 7-8yrs☐; Over 8yrs☐

Q5. Number of projects with e-procurement you have been involved in.

1☐; 2☐; 3☐; 4☐; 5☐; 6☐; 7☐; Over 7☐

Q6. Which type(s) of e-procurement tools have you used for projects? (select all that apply).

e-Tendering☐; e-Invoicing☐; e-Auction☐; Other(s) (please specify): _________

Q7. What stages of the project have you been involved in? (select all that apply).
Pre-contract stage☐; Post-contract stage☐

Section B: General Statements about E-procurement Adoption for Projects.

Q1. How would you rate with the following statements regarding your experience with e-procurement adoption and implementation in Ghana? **1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high.**

No.	Statements	Level of impact Low ⟺ High
1	Effect of hindrances experienced in e-procurement implementation and usage progress	☐1; ☐2; ☐3; ☐4; ☐5
2	Influence of strategic measures on ensuring e-procurement implementation on projects	☐1; ☐2; ☐3; ☐4; ☐5

Q2. How would you **agree** or **disagree** with the following statement about project characteristics for influencing e-procurement adoption? **1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree.**

No.	Project characteristics	Level of agreement Low ⟺ High
1	Degree of dispersion of project	☐1; ☐2; ☐3; ☐4; ☐5
2	Anticipation of high project complexities	☐1; ☐2; ☐3; ☐4; ☐5
3	Structuring and automation of project processes	☐1; ☐2; ☐3; ☐4; ☐5
4	Modern information technology to project procurement	☐1; ☐2; ☐3; ☐4; ☐5

Section C: Drivers, Barriers and Promotion Strategies for the adoption of E-procurement for Sustainable Construction

Q6. **Main Drivers for Adopting E-procurement**. How would you agree to the following as the main drivers for adopting e-procurement? Please use the rating, **1=strongly disagree; 2= disagree; 3= neutral; 4= agree; 5= strongly agree.**

No	Drivers for e-procurement adoption	Level of agreement Low ⟺ High
1	Reduce process, transaction and administrative cost	☐1; ☐2; ☐3; ☐4; ☐5
2	Reduce cycle times for process and transaction	☐1; ☐2; ☐3; ☐4; ☐5
3	Improve efficiency and effectiveness in the process	☐1; ☐2; ☐3; ☐4; ☐5
4	Fast exchange of information among stakeholders	☐1; ☐2; ☐3; ☐4; ☐5
5	Ease of access to information and management of project data	☐1; ☐2; ☐3; ☐4; ☐5
6	Improve response, accuracy and flexibility of process	☐1; ☐2; ☐3; ☐4; ☐5
7	Improved communication with stakeholders	☐1; ☐2; ☐3; ☐4; ☐5
8	Increase transparency, trust and reliability of the process	☐1; ☐2; ☐3; ☐4; ☐5
9	Increase competition among contractors through wide coverage	☐1; ☐2; ☐3; ☐4; ☐5
10	Improve quality of process and error minimization	☐1; ☐2; ☐3; ☐4; ☐5
11	Streamlining and integration of process	☐1; ☐2; ☐3; ☐4; ☐5
12	Reduce staffing	☐1; ☐2; ☐3; ☐4; ☐5
13	Enhancing competitive advantage of firm	☐1; ☐2; ☐3; ☐4; ☐5
14	Effective monitoring of process (real time)	☐1; ☐2; ☐3; ☐4; ☐5
15	Platform for collaboration and supporting added value services	☐1; ☐2; ☐3; ☐4; ☐5
16	Promoting paperless environment	☐1; ☐2; ☐3; ☐4; ☐5
17	Improved Audit trail and accountability	☐1; ☐2; ☐3; ☐4; ☐5
18	Client satisfaction	☐1; ☐2; ☐3; ☐4; ☐5

19	Enhance inventory/archiving and document management	☐1; ☐2; ☐3; ☐4; ☐5
20	Develop knowledge and technological skills of employees	☐1; ☐2; ☐3; ☐4; ☐5
21	Knowledge data base and preserving corporate memory	☐1; ☐2; ☐3; ☐4; ☐5
22	Enhance regulatory compliance on contracts	☐1; ☐2; ☐3; ☐4; ☐5
23	Reduce transportation energy resources	☐1; ☐2; ☐3; ☐4; ☐5
24	Reduce bid collusion and corrupt practices	☐1; ☐2; ☐3; ☐4; ☐5
25	Access to internet intelligent tools for decision-making	☐1; ☐2; ☐3; ☐4; ☐5
26	Better working opportunities	☐1; ☐2; ☐3; ☐4; ☐5
Please list and rate other barriers that may have been omitted in this questionnaire.		
1		☐1; ☐2; ☐3; ☐4; ☐5
2		☐1; ☐2; ☐3; ☐4; ☐5
3		☐1; ☐2; ☐3; ☐4; ☐5
4		☐1; ☐2; ☐3; ☐4; ☐5

Q7. **Barriers to the Adoption of E-procurement**. How critical are the following barriers to the adoption of e-procurement? Please use the rating, **1= not critical; 2= less critical; 3= neutral; 4= critical; 5= very critical.**

No	Barriers to e-procurement adoption	Level of criticality Low ⟺ High
1	Perceive technology as disruptive	☐1; ☐2; ☐3; ☐4; ☐5
2	Resistance to change attitude and behaviour	☐1; ☐2; ☐3; ☐4; ☐5
3	Electronic authentication and authorization issues	☐1; ☐2; ☐3; ☐4; ☐5
4	Unreliable internet service and power supply	☐1; ☐2; ☐3; ☐4; ☐5
5	Violations of data integrity and possibility of data loss	☐1; ☐2; ☐3; ☐4; ☐5
6	Lack of trust and confidentiality of the electronic system	☐1; ☐2; ☐3; ☐4; ☐5
7	Lack of information technology (IT) infrastructure and capability	☐1; ☐2; ☐3; ☐4; ☐5
8	Lack of legal rules and regulations for e-procurement	☐1; ☐2; ☐3; ☐4; ☐5
9	Lack of awareness and access to e-procurement technology	☐1; ☐2; ☐3; ☐4; ☐5
10	Lack of electronic contract enforcement	☐1; ☐2; ☐3; ☐4; ☐5
11	Low level availability of technical expertise/skills	☐1; ☐2; ☐3; ☐4; ☐5
12	Lack of user friendliness and flexibility of e-procurement system	☐1; ☐2; ☐3; ☐4; ☐5
13	High cost of technology investment	☐1; ☐2; ☐3; ☐4; ☐5
14	Fear for reducing bribery and procurement malpractices	☐1; ☐2; ☐3; ☐4; ☐5
15	Fear for job loss (partial technological compliance by staff)	☐1; ☐2; ☐3; ☐4; ☐5
16	Lack of demonstration of firms achieving benefits	☐1; ☐2; ☐3; ☐4; ☐5
17	Insufficient management support for e-procurement	☐1; ☐2; ☐3; ☐4; ☐5
18	Unreadiness of business partners	☐1; ☐2; ☐3; ☐4; ☐5
19	Uncertainty of e-procurement technology maturity and interoperability	☐1; ☐2; ☐3; ☐4; ☐5
20	Other competing initiatives of firm and lack of corporate strategy	☐1; ☐2; ☐3; ☐4; ☐5
21	Lack of incentives for e-procurement adoption	☐1; ☐2; ☐3; ☐4; ☐5
Please list and rate other barriers that may have been omitted in this questionnaire.		
1		☐1; ☐2; ☐3; ☐4; ☐5
2		☐1; ☐2; ☐3; ☐4; ☐5
3		☐1; ☐2; ☐3; ☐4; ☐5
4		☐1; ☐2; ☐3; ☐4; ☐5

Q8. **Strategies for Promoting E-procurement**. Please, rate the importance of the following strategies for promoting the adoption of e-procurement. **1= not important; 2= less important; 3= neutral; 4= important; 5= very important.**

No.	**Strategies to promote e-procurement adoption**	**Level of importance** Low ⟺ High
1	Align e-procurement to organisation's strategy and contextual procurement procedures.	☐1; ☐2; ☐3; ☐4; ☐5
2	Incentives and reward schemes for e-procurement adoption on projects	☐1; ☐2; ☐3; ☐4; ☐5
3	Competent institutional framework and local promotion teams for effective e-procurement implementation	☐1; ☐2; ☐3; ☐4; ☐5
4	Enable collaborative environment among organisations and partners	☐1; ☐2; ☐3; ☐4; ☐5
5	E-procurement related educational and training programs for client organisations, property developers, contractors and policy makers.	☐1; ☐2; ☐3; ☐4; ☐5
6	An active and strengthened research and development for e-procurement implementation	☐1; ☐2; ☐3; ☐4; ☐5
7	Pilot implementation projects for contextual learning and knowledge sharing	☐1; ☐2; ☐3; ☐4; ☐5
8	Proactive change-management methods and innovation culture	☐1; ☐2; ☐3; ☐4; ☐5
9	Organisational leadership buy-in and commitment strategy for e-procurement implementation	☐1; ☐2; ☐3; ☐4; ☐5
10	Active publicity through media (e.g. internet, print media, television)	☐1; ☐2; ☐3; ☐4; ☐5
11	Availability of quantifiable evidence of e-procurement benefits	☐1; ☐2; ☐3; ☐4; ☐5
12	Ensure standardisation and simplification of process across systems	☐1; ☐2; ☐3; ☐4; ☐5
13	Mandatory e-procurement policies and regulations	☐1; ☐2; ☐3; ☐4; ☐5
14	Availability of financial support schemes for e-procurement technology investment	☐1; ☐2; ☐3; ☐4; ☐5
Please list and rate other strategies that may have been omitted in this questionnaire.		
1		☐1; ☐2; ☐3; ☐4; ☐5
2		☐1; ☐2; ☐3; ☐4; ☐5
3		☐1; ☐2; ☐3; ☐4; ☐5
4		☐1; ☐2; ☐3; ☐4; ☐5

The End-
Many thanks for your participation

APPENDIX B

QUESTIONNAIRE FOR AHP SURVEY

Dear Sir/Madam

Research into promoting electronic procurement adoption in Ghanaian Construction Projects

We are highly grateful for participating in the first questionnaire survey which identified important benefits/drivers of e-procurement adoption in Ghana. You are hereby selected as one of the most qualified experts based on your background information and experience provided, to evaluate the benefits by assigning importance weights using pairwise comparison. This is needed to prioritize the benefits to help practitioners and other stakeholders make tradeoffs among them, especially deciding which should be assessed with limited resources availability.

We humbly request your assistance in evaluating the comparability of important e-procurement benefits using the analytic hierarchy process (AHP) to complete this survey based on your experience and judgements. The outcome of this research aids in developing a decision model, and as a result help improve e-procurement benefits evaluation for the construction industry in Ghana. Please see below the research problem and guidelines needed for completing the questionnaire.
Be assured that your responses are anonymous and will be used only for academic purpose.

Problem

You are presented with the problem of selecting the benefits of e-procurement which could be assessed when implemented for a construction project in Ghana. The client indicates of numerous benefits of e-procurement hence it has become difficult to select key benefits and the required criteria needed to measure these benefits. It the clients desire to select best optimal benefits and criteria which could be comprehensively employed for benefit measurement. You have decided to provide the client with expert advice and knowledge for the choice of benefits and the suitable criteria based on their relative importance and to use the analytic hierarchy process to make choices that best solves the concerns of the client.

Guidelines for assigning importance weights

By means of pairwise comparisons, each benefit will be assessed to indicate the strength with which it dominates another with respect to the category under which they are compared and in terms of achieving the main goal (i.e., measured and quantified). The scale to assign the importance weights is a 9-point scale defined in the table below.

SCALE

Weight	Definition	Explanation
1	Equal importance	Two e-procurement benefits contribute equally to the objective
3 (or 1/3)	Moderate importance	Experience and judgment slightly favor one benefit over another
5 (or 1/5)	Essential or strong importance	Experience and judgment strongly favor one benefit over another
7 (or 1/7)	Very strong importance	A benefit is very strongly favored over another
9 (or 1/9)	Absolute/extreme importance	A benefit is extremely favored over another
2,4,6,8	Intermediate values between the two adjacent judgments	When comprise is necessary between two judgements

Two benefits can be weighted from 1 to 9 depending on whether they are equal or one is more important. The benefit which is less important takes the inverse of the scale. It can be found from the table above that when two benefits have an equal importance, a score of 1 is assigned. This normally occurs when a benefit is compared with itself. When one benefit is from moderately to strongly important, it takes a score of 4 and so on, and you can continue to quantify how much each benefit is preferred to the other.

For example, in the table below, 'reduce process, transaction and administrative cost' is moderately important than 'Improved communication with stakeholders', and very strongly important than 'Enhancing competitive advantage of firm'. This means that when 'Improved communication with stakeholders' is compared with 'reduce process, transaction and administrative cost', then 'improved communication with stakeholders s' is preferred by 1/3 of 'reduce process, transaction and administrative cost'.

Pairwise comparison example

Electronic procurement systems benefits	Reduce process, transaction and administrative cost	Improved communication with stakeholders	Enhancing competitive advantage of firm
Reduce process, transaction and administrative cost	1	3	7
Improved communication with stakeholders	1/3	1	4
Enhancing competitive advantage of firm	1/7	1/4	1

Please note that the questionnaire for the pairwise comparison is located on the next pages which will take approximately 25 minutes to complete. The researcher will be available during the comparison evaluation to assist in dealing with any issues or problems you may encounter.
Many thanks for your feedback and support for this research.

For any further queries, please contact me on Tel.: +23324370 /+8529296 ; and email: sitsofe-k.yevu@

Yours sincerely, highly

Sitsofe K. Yevu, PhD Candidate
Associate Professor Ann T. W. Yu, Department of Building and Real Estate
The Hong Kong Polytechnic University
Hong Kong

Pairwise Comparison Questionnaire

Q1. Please indicate the level of relative importance/preference of each procurement governance improvement benefit compared to each other for quantitative measurement in the construction industry in Ghana.

Pairwise comparison for benefits in procurement governance improvement

Benefits/Drivers	Effective monitoring of process (real time)	Promoting paperless environment	Improved Audit trail and accountability	Reduce bid collusion and corrupt practices
Effective monitoring of process (real time)	1			
Promoting paperless environment		1		
Improved Audit trail and accountability			1	
Reduce bid collusion and corrupt practices				1

Q2. Please indicate the level of relative importance/preference of each process optimization benefit compared to each other for quantitative measurement in the construction industry in Ghana.

Pairwise comparison for benefits in process optimization

Benefits/Drivers	Reduce process, transaction and administrative cost	Reduce cycle times for process and transaction	Improve efficiency and effectiveness in the process	Improve response, accuracy and flexibility of process
Reduce process, transaction and administrative cost	1			
Reduce cycle times for process and transaction		1		
Improve efficiency and effectiveness in the process			1	
Improve response, accuracy and flexibility of process				1

Q3. Please indicate the level of relative importance/preference of each integrity assurance and environmental sustainability benefit compared to each other for quantitative measurement in the construction industry in Ghana.

Pairwise comparison for benefits in integrity assurance and environmental sustainability

Benefits/Drivers	Increase transparency, trust and reliability of the process	Enhance regulatory compliance on contracts	Reduce transportation energy resources
Increase transparency, trust and reliability of the process	1		
Enhance regulatory compliance on contracts		1	
Reduce transportation energy resources			1

Q4. Please indicate the level of relative importance/preference of each information management systems benefit compared to each other for quantitative measurement in the construction industry in Ghana.

Pairwise comparison for benefits in information management systems

Benefits/Drivers	Ease of access to information and management of project data	Improved communication with stakeholders	Platform for collaboration and supporting added value services	Enhance inventory/archiving and document management
Ease of access to information and management of project data	1			
Improved communication with stakeholders		1		
Platform for collaboration and supporting added value services			1	
Enhance inventory/archiving and document management				1

Q5. Please indicate the level of relative importance/preference of each client performance values benefit compared to each other for quantitative measurement in the construction industry in Ghana.

Pairwise comparison for benefits in client performance values

Benefits/Drivers	Fast exchange of information among stakeholders	Client satisfaction
Fast exchange of information among stakeholders	1	
Client satisfaction		1

Q6. Please indicate the level of relative importance/preference of each smart resource systems benefit compared to each other for quantitative measurement in the construction industry in Ghana.

Pairwise comparison for benefits in smart resource systems

Benefits/Drivers	Reduce staffing	Access to internet intelligent tools for decision-making
Reduce staffing	1	
Access to internet intelligent tools for decision-making		1

The End-
Many thanks for your time!

APPENDIX C

VALIDATION QUESTIONNAIRE

THE HONG KONG POLYTECHNIC UNIVERSITY 香港理工大學 | DEPARTMENT OF BUILDING & REAL ESTATE 建築及房地產學系

Questionnaire for Validating the Implementation System Model in the Promotion of Electronic Procurement Systems Implementation in Ghana

Purpose of survey

To validate that the implementation system model for promoting electronic procurement systems (EPSs) implementation in the construction industry is credible, reliable, practical, inclusive and appropriate for use in the Ghanaian construction environment.

Background

The variables captured and the implementation system model developed were part of deliverables for a PhD research study conducted at The Hong Kong Polytechnic University in Hong Kong by Mr. Sitsofe Kwame Yevu, under the supervision of Dr. Ann T. W. Yu. Overall, this study aimed at developing a model that examines the influential issues for EPS promotion in developing countries. The implementation system model was derived from the results in a general questionnaire survey and an analytic hierarchy process (AHP) survey involving procurement professionals in Ghana. The surveys were conducted from January to June 2020.

Instructions

This document has 6 pages (page 1 presents the background and instructions, and 5 pages present the implementation system model for EPSs). After examining the sections of the implementation system model, you are kindly requested to indicate your level of agreement with statements aimed at validating the implementation system model at the end of the document.

Expert's background information

1. Sector of operation: ☐ Public ☐ Private ☐ Others, please specify ____________.
2. Type of organization: ________________________________.
3. Position in organization: ________________________________.
4. Years of experience: ______________________.

Your kind assistance in completing this questionnaire will be much appreciated. Kindly return the completed questionnaire to Mr. Sitsofe Kwame Yevu by email (sitsofe-k.yevu@) within two weeks.

Thank you very much in advance for your kind contribution.

Yours sincerely,
Sitsofe Kwame Yevu (PhD Candidate)
Dr. Ann T. W Yu (Supervisor, Department of Building and Real Estate, Hong Kong Polytechnic University)

An Implementation System Model for EPSs Implementation in Ghana

In developing the implementation system model to promote EPSs implementation in Ghana, various processes were applied on the influential issues, i.e. EPSs benefit drivers, barriers and strategies. Initially, the important benefit drivers, barriers and strategies promoting EPSs were identified and grouped to reveal the underlying constructs of these influential issues in Ghana, respectively. The underlying constructs and their respective items for the benefit drivers, barriers and strategies are provided Table 1. For EPSs benefit drivers, the fuzzy synthetic evaluation results showed the six groups of benefit drivers were significant in creating a suitable climate for EPS adoption (see Fig. 1). Subsequently, AHP was applied to the six underlying constructs of EPS benefit drivers to determine the most preferred benefit driver for quantitative evaluation as shown in Fig 1. Regarding the barriers and strategies, the neuro-fuzzy model results showed dynamic influences of these influential issues on EPSs implementation in Ghana (Fig. 2).

Based on the results from the aforementioned procedures, an implementation system model for EPSs implementation in Ghana was developed in this study. Since the implementation system model figure size is large, it has been comprehensively presented in three parts to aid evaluators understand the model (Fig. 1-3). In support of this, the details of the implementation system model comprised of two sections in its development, i.e. the upper section – EPSs benefit drivers and quantitative evaluation and the lower section – EPSs barriers and strategies.

Fig. 1 shows the six categories of EPS benefit drivers that has high tendencies of creating a suitable climate for EPS adoption in projects. Also, in Fig. 1, the individual EPS benefit drivers preferred for quantitative evaluation from the groups are presented with suggested indicators to adopt for assessment. Fig. 2 demonstrates the dynamic interactions among grouped barriers that could result in high or low hindrance influence levels to EPS usage in project environments on the left. Further, Fig. 3 presents the effective synergistic influences of clustered strategies promoting EPS implementation.

Table 1 Constructs and their measured item

Code	Construct	Measured Items
	Benefit Drivers for EPSs use	
IERF	Integrity and environment-related forces	Effective monitoring of process (real time) Promoting paperless environment Improved audit trail and accountability Reduce bid collusion and corrupt practices
PORF	Process optimization-related forces	Reduce process, transaction and administrative cost Reduce cycle times for process and transaction Improve efficiency and effectiveness in the process Improve response, accuracy and flexibility of process
FCRF	Fairness and conformance-related forces	Increase transparency, trust and reliability of the process Enhance regulatory compliance on contracts Reduce transportation energy resources
IIRF	Information integration-related forces	Ease of access to information and management of project data

		Improved communication with stakeholders Platform for collaboration and added value services Enhance inventory/archiving and document management
CRF	Client-related forces	Fast exchange of information among stakeholders Client satisfaction
SRSRF	Smart resource system-related forces	Reduce staffing Access to internet intelligent tools for decision-making
	Barriers to EPSs adoption	
HRB	Human-related barriers	Resistance to change attitude Lack of demonstration of firms achieving benefits Insufficient management support for EPSs Unreadiness of business partners
TRRB	Technological risk-related barriers	Electronic authentication and authorization issues Unreliable internet service and power supply Violations of data integrity and possibility of data loss Lack of IT infrastructure and capability
RRB	Regulation-related barriers	Lack of legal rules and regulations for EPSs Lack of electronic contract enforcement
IGRB	Industry growth-related barriers	Uncertainty of EPSs technology maturity Lack of incentives for EPSs adoption
FRB	Financial-related barriers	High cost of technology investment Fear for reducing bribery and procurement malpractices
	Strategies promoting EPS implementation	
TE	Technology education	EPSs related training programs for key stakeholders Active and strengthened research and development for EPSs implementation Pilot implementation projects for contextual learning and knowledge sharing Active publicity through media communications Availability of quantifiable evidence of EPSs benefits
ICM	Innovation culture management	Proactive change-management methods Organizational leadership buy-in and commitment strategy for EPSs
TSE	Technology stimulation environment	Mandatory EPSs policies and regulations Availability of financial support schemes for EPSs investment
IPM	Incentives and partnership mechanism	Reward schemes for EPSs adoption on projects Enable collaborative environment among organizations and partners
OIS	Organizational integration support	Align EPSs to organization's strategy and procurement procedures. Competent institutional framework and local promotion teams for effective EPSs implementation

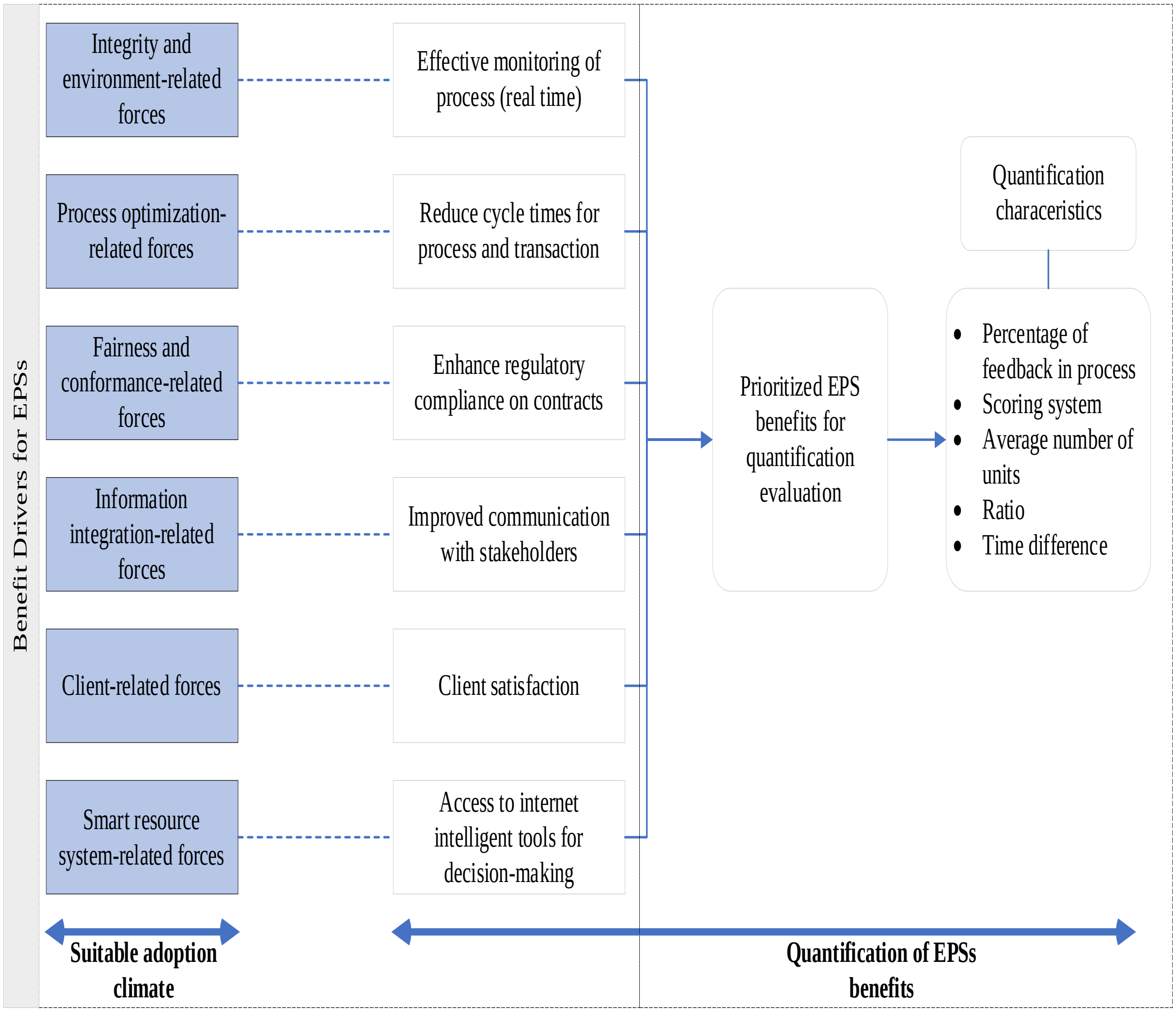

Fig. 1 Benefit Drivers fof EPS adoption and preferred benefits for quantitative assessment.

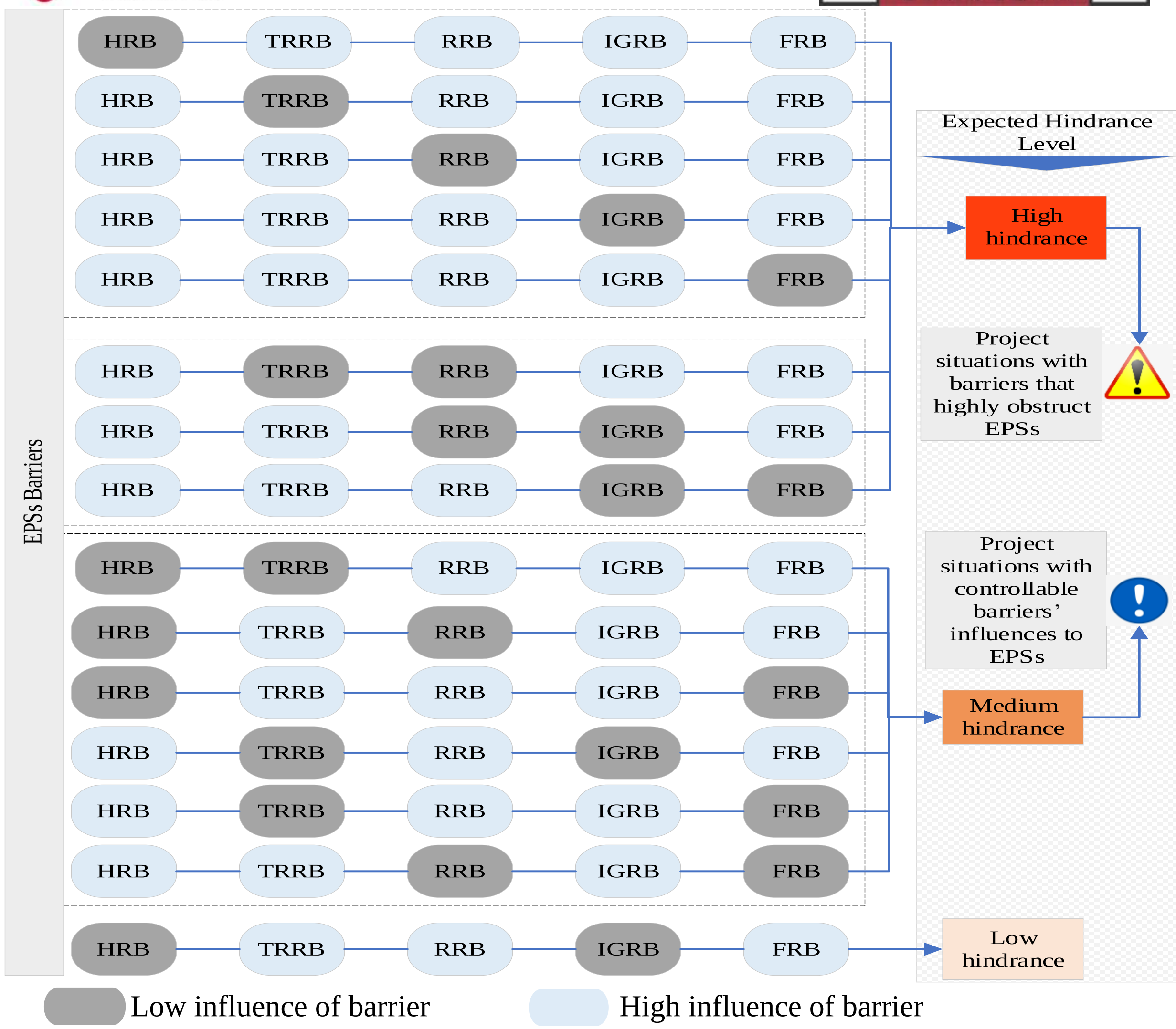

Fig. 2 Influence interactions among grouped barriers and the effects on EPS adoption.

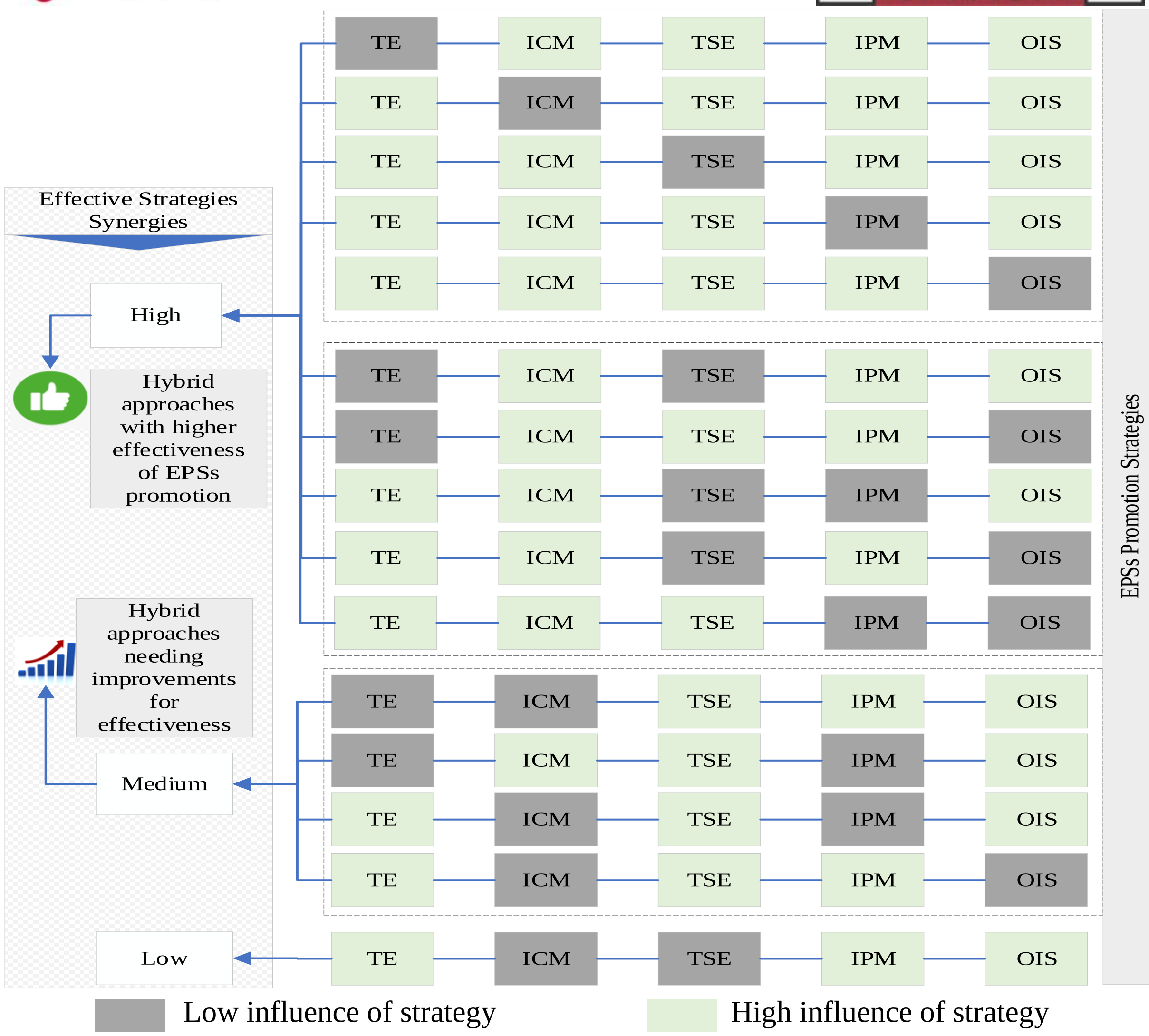

Fig. 3 Synergistic influences of clustered strategies promoting EPSs implementation.

THE HONG KONG POLYTECHNIC UNIVERSITY 香港理工大學

DEPARTMENT OF BUILDING & REAL ESTATE 建築及房地產學系

Validation Questionnaire for the Implementation System Model for EPSs

Please indicate your level of agreement with the following validation aspects/statements about the implementation system model to promote EPSs in Ghana (Fig. 1-3). Kindly use the evaluation scale: 1 = strongly disagree; 2 = disagree; 3 = moderate; 4 = agree; 5 = strongly agree.

No.	Validation aspects/statements	Evaluation scale
		Low ⇔ High
1	The significant elements, that is, EPSs benefit drivers, barriers, and strategies identified are reasonable and critical in the GCI.	□1; □2; □3; □4; □5
2	The EPSs implementation system model is easily understandable and can be used in Ghana.	□1; □2; □3; □4; □5
3	The guides and steps within the EPSs implementation system model are appropriate	□1; □2; □3; □4; □5
4	The EPSs implementation system model is inclusive and comprehensive for all necessary EPSs elements	□1; □2; □3; □4; □5
5	The appropriate application of the EPSs implementation system model would successfully help promote EPSs usage in the GCI.	□1; □2; □3; □4; □5
6	Overall, the EPSs implementation strategy is suitable for promoting EPSs uptake in Ghana.	□1; □2; □3; □4; □5

Please, if any, kindly provide general comments on the EPSs implementation system in the box below.

~ The End ~

Thank you for your valuable time, participation and support

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