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An Enterprise Reference Architectural method for the business RM of the Construction sector- Development and Evaluation

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Abstract: The ecosystem of the construction enterprises is not well-defined, resulting in the inability to identify the ICT measurements including ICT gaps, ICT duplicative levels, and future ICT investments. Business reference models (RM) are human graphical interpretation models resulting from cross agency analysis of the structural elements and functional operations of enterprises. An Enterprise Reference Architectural method and RM are developed based on the integration of the Design science research phases (DSR) and the Enterprise architecture (EA) discipline. The six phases of DSR based method orchestrated the development of an RM for the AEC/Construction sector in conjunction with a customized open group architectural framework (TOGAF), ArchiMate modeling language, and an exploratory in-depth Case Study for an AEC/Construction case. The developed method and resulting business RM were evaluated based on Delphi technique and empirically scored 73% of appropriateness w.r.t eleven quality parameters.

Keywords: *Enterprise reference architectural method, AEC/Construction, TOGAF, case study, reference model (RM).*

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INTRODUCTION

The AEC/Construction entails the collection of the life cycle sub-processes of a building project (Björk, 1999); (Volker & Klein, 2010), at which the AEC/construction enterprises are service oriented (i.e. Services are intangible, heterogeneous, and inseparable) (Winch & Schneider, 1993); (Van Andel & Vandenbempt, 2012), professional (Van Andel & Vandenbempt, 2012), and knowledge- based (Schön, 1984); (Walker, 2011) . However, despite its remarkable contribution to the economic growth, the AEC/construction sector is not yet well defined nor understood and lacks common definition (Ofori, 2015). Also, the output levels of construction measure and impact the construction processes. Those levels are impacted by the utilized ICT along with its tools, users, processes, and costs (Odubiyi, Aigbavboa, & Thwala, 2019); (Moshood, Nawanir, Sorooshian, Mahmud, & Adeleke, 2020). Therefore, internationally, including Bahrain, a deficiency in holding common structural elements and functional operations into a standard reference architectural model (RM) of the construction sector negatively impacts the capability of identifying the appropriate ICT measurement constructs including ICT gaps, ICT duplicative levels, and future ICT investments (Björk, 1999); (Volker & Klein, 2010).

The Reference models (RM) practice has arisen in several information systems and system engineering fields (Cloutier et al., 2010) to demonstrate generic solution patterns to design domain specific systems and mitigate the complexity of the IT landscape (Niemann, 2010), constitute organization-specific configuration (Winch & Schneider,

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1993), and form a representation of a homogeneous groups of components (Spewak, 1992); (Dube & Dixit, 2011), express "a point of reference for the development of specific models" (Thomas, 2005), facilitate cross agency analysis, and identify duplicative ICT investments, gaps, and opportunities (Ahmadi, Soltani, & Gheitasi, 2007).

The Reference model (RM) practice is interrelated with the Enterprise architecture (EA) discipline at which EA unifies the business architectural landscape in the form of graphical architectural blueprints (Hinkelmann et al., 2016) of every AEC/construction enterprise within the sector by the utilization of an EA Framework (EAF) such as TOGAF and ArchiMate modeling language. TOGAF was selected amongst other frameworks to define and describe the architectural artefacts of enterprise such as the strategic objectives, services, functions, processes, actors, and their overall relationships (ISO, 2011); (Alaeddini & Salekfard, 2013); (Bandeira, 2023); (Zachman, 1987); (Group, 2024) to structure EA levels into business architecture (BA), information systems architecture (ISA), and technology architecture (Dietz et al., 2013), while ArchiMate was selected as the best integrated architecture description language (ADL) for the graphical description of an enterprise architectures (Lankhorst, Proper, & Jonkers, 2010); (Ofori, 2015).

Previous works about reference models, as appearing in Table1, were proposed to represent the business processes for nine specific industries and for several purposes, including the works of (Ahmadi et al., 2007) for IT management, (Pesic & Van Der Aalst, 2005) for software systems, (?, ?); (?, ?) for smart cities, and (Giachetti, 2012) for military system tools. However, literature reviewing shows scarcity of reference architectural modeling for the AEC/construction domain as survey revealed limited research works of RM development in project management without the interference of EA, such as the work of (Björk, 1999) in addition to (Mirarchi, Naville, David, Pastorelly, & Zarli, 2021); (Bedoiseau, Martin, & Boton, 2022); (Mirarchi, Pavan, Gatto, & Angotti, 2023) at which all developed RMs act as a basis for implementing computer applications, documentation purposes, or presented a model of information and material activities, or studied the ontology based IS management in construction process.

The current research work proposes an Enterprise Architectural method for the development and generation of a unified EA based business RM for the AEC/construction sector, aiming at easing their future measurement of ICT constructs. Consequently, a six phased design science research technique (DSRM) was selected and utilized according to (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007); (Hevner, March, Park, & Ram, 2004) as a problem-solving process to solve enterprises problems, by creating and evaluating IT artifacts (i.e., EA based business RM model) and aligning the theoretical background of enterprises into real-world outcomes (Group, 2024). Drawing on this rigorous EA based method, TOGAF, is tailored and coincided with Case Study approach (Ritchie, Lewis, Nicholls, & Ormston, 2003); (?, ?); (Shakir, 2002); (Benayat, 2023); (Ritchie et al., 2003) to enable the collection (Yin, 2018), (Ritchie et al., 2003), analysis (Ritchie et al., 2003), design , implementation (?, ?), testing, and evaluation (Ritchie et al., 2003); (Skinner, Nelson, Chin, & Land, 2015) of the structural components, functional components, and interactions between the business strategic objectives, services, functions, processes, divisions, participants, and of an AEC/construction enterprise.

Drawing on the empirical results of the current study design, the exploratory in-depth Case Study is expected to orchestrate the business reference model design process and prescribe necessary adjustments to the upcoming comprehensive reference business architecture method and RM development of the AEC/construction sector.

This research work contributes in providing 1) a comprehensive investigation of the AEC/Construction sector. From one side, it reviews the sector from well established literature and from the other hand it investigates the sector practically through an explorative and in-depth Case study, 2) the development of a rigorous Enterprise Reference Architectural method which integrates multiple well-established disciplines, 3) the development of the business RM which paves the way better ICT maturity measurement initiatives, and 4) the evaluation of the work.

The paper is composed of five sections at which Section 2 reviews the AEC/Construction sector and explains the related work to the problem at hand, while Section 3 explains the design science research (DSR) methodology, under which the entire study was implemented. Alternatively, Section 4 executes the first phase of the DSR and introduces the start-up business RM and elaborates on the initial model demonstrating the construction (i.e. design and development) process of the RM, demonstrating the Case Study and data collection at which the collected data is analysed, and the empirical findings are pronounced through testing and evaluation methods, while Section 5 concludes and builds on the findings.

LITERATURE REVIEW

The AEC/Construction Enterprises

Construction entails the collection of the life cycle sub-processes of a building project including pre-design, design, construction, operation and maintenance, and a multitasking activity to build infrastructure (Björk, 1999). According to (Volker & Klein, 2010), six architectural design enterprise types result from the integration of three business models such as, service, experience, and signature focus, and two organizational structures such as, organic and mechanic. Enterprises of service focus in combination with an organic organizational structure offering a high service level at routine tasks at which their organizational structure is simple, less formalized, and more participative with employees of a lower level. However, the structure of enterprises of experience is complex, less formalized and less participative with employees. Table 1 demonstrates several construction enterprises based on (Rivard et al., 2004); (El-Diraby, 2014); (Peh & Low, 2013); (Succar, 2009); (Schapke, Menzel, & Scherer, 2002); (Ercoskun & Kanoglu, 2003); (Eastman, 2011).

Table 1 *TYPES OF AEC/CONSTRUCTION ENTERPRISES*

Enterprise type	Country	Year	Found in
AEC	Canada	2004, 2014	(Rivard et al., 2004) , (El-Diraby, 2014)
A/E	Singapore, Malaysia	2013	(El-Diraby, 2014)
AECO	Australia	2009	(Succar, 2009)
A/E/C & FM	Slovenia, Germany	2002	(Schapke et al., 2002)
AEC/EPC	USA	2003, 2011	(Ercoskun & Kanoglu, 2003) , (Eastman, 2011)

According to (Winch & Schneider, 1993); (Van Andel & Vandenbempt, 2012), AEC/construction enterprises are service oriented, professional, and knowledge- based (Schön, 1984); (Walker, 2011). Services are intangible, heterogeneous, and inseparable. Professionalism corresponds to deep practice of standards and procedures, while creativity corresponds to innovation which is divided into economic and symbolic values, such as appearance and reputation (Walker, 2011). Also, (Schön, 1984); (Walker, 2011) consider knowledge-based enterprises consider that staff expertise are their business assets. Therefore, complexity and fragmentation of construction projects necessitate higher no of actors in the construction services. Therefore, construction enterprises deliver full services within the architecture, engineering and construction stages of construction projects (Van Andel & Vandenbempt, 2012). Illustrated in Table 2, the research survey revealed that AEC enterprises have fallen under three project protocols at which the royal institute of British architect's plan (RIBA) is an 11 operational plan of work for construction throughout the AEC/construction sector. The generic design and construction process protocol (GDCP) is a 10-process method while the International Council for Building (CIB) aims to facilitate information exchange between governmental research institutes, and ISO 12006 is a 5 processes international standard that structures info for construction. Alternatively, outlined in Table 3, the construction activities range from 4 processes in Brazil (Michaloski & Costa, 2010), to 4 processes in UK (Amor, Betts, Coetzee, & Sexton, 2002), 6 processes in both USA and Turkey (Björk, 1999), (Cakmak & Tas, 2012) and 9 processes in South Africa (Malcolm Murray & Lai, 2001). According to (Schön, 1984), the architectural design process, tasks and actors are described as an integrated knowledge-intensive activity. According to (Walker, 2011), architects perform design activities, structure design communication, and do architectural documentation.

Table 2 *THE CONSTRUCTION BUILDING PROTOCOLS*

RIBA	GDCPP	CIB	ISO 12006
Client request appraisal	Demonstrating the need	Conception of needs	Inception/Procurement
Briefing preparation	Need conception	Team selection	Feasibility
Outline proposals	Outline feasibility	Briefing and design	Proposal preparation
Detailed proposals	Feasibility study	Construction	Scheme design/Costing
Information production	Full conceptual design		Tender action
Tender documentation	Design and procurement		Construction initiation
Tender action	Production information	Facility management	Construction operation
Mobilization	Construction		Completion
Construction 2 complete	Operation & aintenance		Feedback

Table 3 *THE CONSTRUCTION PROCESS LIFE CYCLE*

Process	Location	Description of project processes.	Found
4	Brazil	Conception of need, tender,design, construction and FM.	(Michaloski & Costa, 2010)
5	UK	Building materials, other materials, equipment, construction, services.	(Amor et al., 2002)
6	USA	Design, Construction, maintenance, use, information activities, material activities.	(Björk, 1999)
6	Turkey	Initiation, design, procurement, construction, operation, disposal.	(Cakmak & Tas, 2012)
9	S.Africa	Inception, predesign, feasibility, approval, finance, detaildesign, cost, tender, construction, FM	(Malcolm Murray & Lai, 2001)

The Reference Models (RM)

Reference models (RM) have arisen in the field of EA, system engineering, and information systems. According to (Cloutier et al., 2010), RMs are abstract solution patterns to design domain specific systems which provide generic solution patterns and mitigate the complexity of the IT landscape (Niemann, 2010), constitute organization-specific configuration (Winch & Schneider, 1993), and form a representation of a homogeneous group of components including, process, system, or area and is developed for the analysis, improvement, and/or replacement of the specified process (Spewak, 1992); (Dube & Dixit, 2011). Also, RMs express "a point of reference for the development of specific models" (Thomas, 2005), facilitate cross agency analysis, and identify duplicative ICT investments, gaps, and opportunities (Ahmadi et al., 2007). Unfortunately, previous studies on EA based RMs development are limited to 9 in many industries including the works of (Pesic & Van Der Aalst, 2005) for software systems, (Adwan, 2018); (Adwan, 2019) for smart cities, (Ahmadi et al., 2007) for IT management, and (Giachetti, 2012) for military system tools. The case is much worse in the AEC/construction domain as survey revealed 7 research works RM development in project management such as (Björk, 1999) in addition to (Mirarchi et al., 2021); (Bedoiseau et al., 2022); (Mirarchi et al., 2023) at which all developed RMs act as a basis for implementing computer applications, documentation purposes, or presented a model of information and material activities, or studied the ontology based IS management in construction process.

EA, TOGAF, ArchiMate

EA is defined by (Hinkelmann et al., 2016) as a blueprint that describes enterprise elements & relationships and organizes the business processes, data, and information technologies. Accordingly, EA comprises graphical models that generate architecture description products. Generated description is the tool that helps in solving complexities of enterprises' knowledge space of reality. The representation of knowledge is interpreted either in a human graphical interpretation or in machine interpretation. (Hinkelmann et al., 2016) argue that modeling is a human practiced task which starts with preferred cognitive graphical models for communication between the stakeholders in the enterprise design. Therefore, for the development of the architectural model, an EA Framework (EAF) is utilized to define and describe the architectural artefacts and relationships. According to (ISO, 2011) EAF is defined as "fundamental concepts or properties of an enterprise embodied in its elements, relationships." The EAF is considered by (Alaeddini & Salekfard, 2013) consider as a provider of a collection of processes, techniques, artefact descriptions, and reference models for production and use of enterprise architecture description. Several EAFs were utilized in industries, including DODAF which provides structure for defence concerns (Bandeira, 2023). FEAF encompasses a set of interrelated "reference models" for cross-agency analysis (Zachman, 1987). Zachman represents the perspectives of different stakeholders (Group, 2024). Alternatively, TOGAF as defined by (Lankhorst et al., 2010) is an iterative model generation framework that categorizes EA levels into business architecture (BA), information systems architecture (ISA), and technology architecture. The BA considers the enterprise business strategy, goals and objectives, technological environment, and the interests of the enterprise stakeholders. The ISA encompasses the application-level aspects which map the information needs to the enterprise's specific business needs. Several modelling languages were developed to describe EA, few of which are intended for human interpretation. ArchiMate modeling language has arisen as an integrated architecture description language (ADL) for graphically describing all aspects of enterprise architectures (Lankhorst et al., 2010) at which it provides concepts for creating a model that maps to its three architectural layers, is intended for human interpretation, serves general enterprise architecture modelling purposes, and is complied with TOGAF (Hinkelmann et al., 2016).

RESEARCH METHOD

Depicted in Figure 1, a six phased design science research technique (DSRM) was selected and utilized according to (Peffers et al., 2007); (Hevner et al., 2004) as a problem-solving process to solve enterprises problems, by creating and evaluating IT artifacts (i.e., EA based business RM model) and aligning the theoretical background of enterprises into real-world outcomes (Dietz et al., 2013).

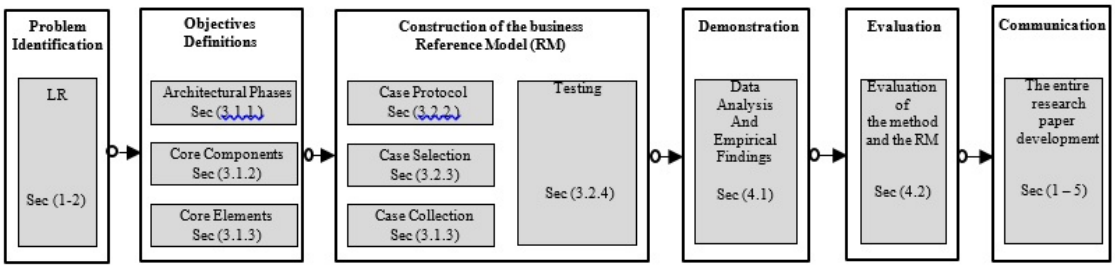

Figure 1 *The DSRM based development method of business RM of AEC/Construction sector.*

The DSR is comprised of six phases namely, problem identification and motivation, definition of the objectives for a solution, design and development of the artifact, demonstration of the artifact, evaluation, and communication of the process to researchers and other relevant professionals. The 1st phase is comprised of two subphases, identification and definition of the objectives. The 3rd phase is identical to Peffer's design and development phase. The 4th phase is the demonstration phase, while evaluation and communication phases correspond to the 5th and 6th phases of Peffer.

Problem Identification and Objectives Definition

From EA perspective, the method of developing a business RM requires a trustworthy EAF (i.e. TOGAF) that is capable of generating the business architectural representation of the enterprise throughout the identification and tailoring of architectural phases and core components to describe the baseline (As-Is) state of it throughout the alignment with the core elements.

The architectural phases and core components : The tailored phases of TOGAF are depicted in Figure 2 to include preliminary, architecture vision, and business architecture. Preliminary seeks to establish the architecture capability desired by the enterprise. Section 5 in Appendix 1 details on the preliminary requirements and describe the architectural scope elements of the project (Dietz et al., 2013). The architecture vision aims at achieving five objectives such as, ensuring the support of management to the architecture development evolution, validating principles, goals, and strategic drivers of the enterprise, identifying the scope of components, defining relevant stakeholders, and articulating the key business requirements, and defining of the as-is state. An architecture vision document was established to illustrate the development tasks as depicted in Appendix 1 (Dietz et al., 2013).

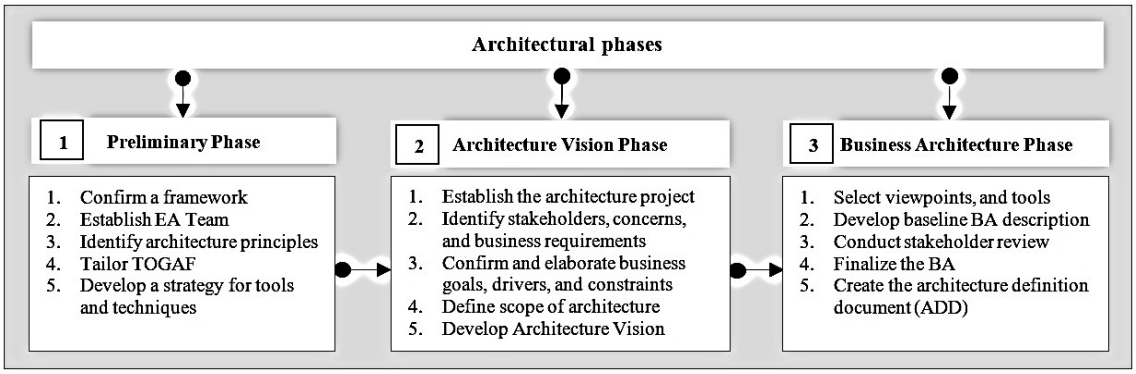

Figure 2 *The architectural representation-based phases and processes*

The core components of an enterprise represent the holistic, multi-dimensional business views of the business capabilities entailing, the strategic objective (SO) view, organization structure view including, units (U), actor/role, processes (P), functions (F), and services (S). Figure 3 depicts the initial architectural representation-based model (RM), at which SO describes the enterprise goals at which the key data collected are id# and name, while U and A/R describe the units and the interaction between actors/roles, at which the key data collected are unit id#, name.

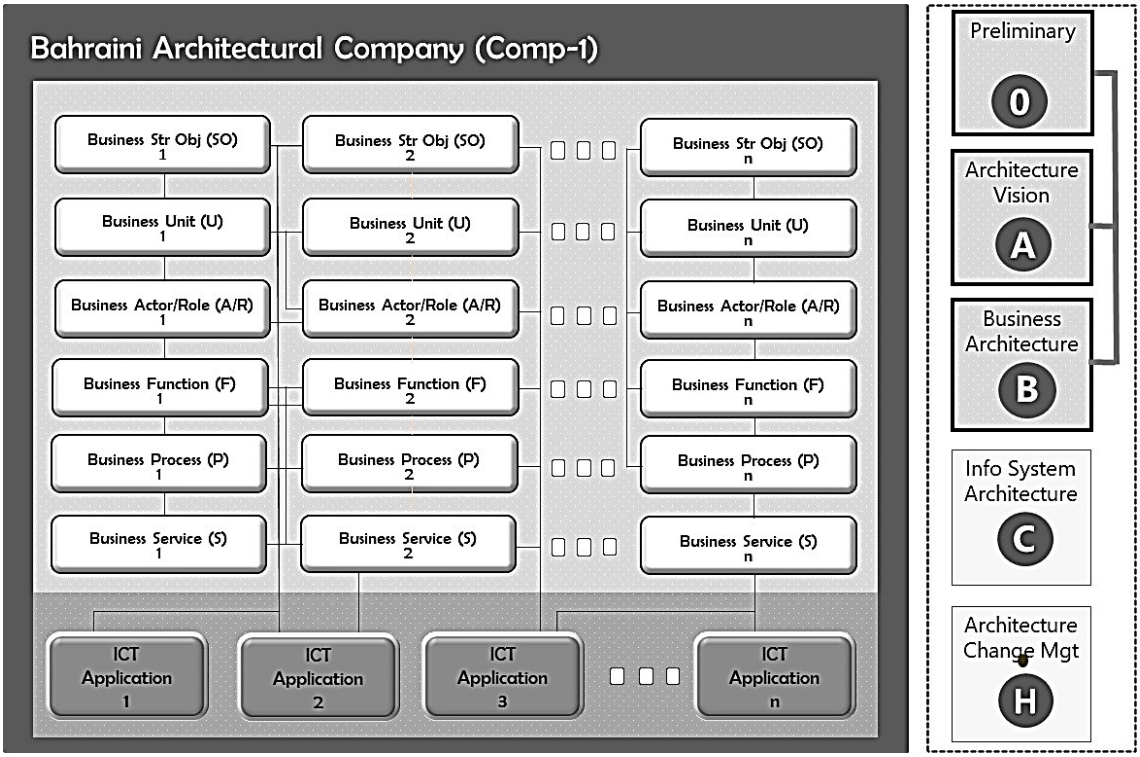

Figure 3 *The initial architectural representation (Conceptual) -based model*

Core components of the business RM :The acronum P describes the processes of carrying out the services (S), depicts the actors and roles carrying out individual activities of each process, categorizes each activity under the process into

automatic / manual / hybrid, documents the information flow across activities, and describes the execution scenario, at which key data collected include process id#, name, description, class, service id#, supplier, and consumer. F describes the functions executed by the units to deliver the SO view, at which key data collected include function- id#, name, unit id#, classification, and SO id#. Finally, S describes the services offered by the units to internal and external customers, at which key data collected are service-id#, name, description, and function- id#. Depicted in Appendix 1, an established set of architecture definition document (ADD) templates to address those As-Is architectural artifacts.

Core elements of the business RM :The business core elements correspond to the business entities and processes. Based on the findings of the literature review, a typical suggested business RM for the case should include business core elements such as, the business strategic mission and vision (SO), the business units (U), the business stakeholders (A/R), the business functions (F), the business processes (P), and the business services (S). However, such elements should first be justified and then mapped to the core components. (Dietz et al., 2013).

Construction of the Business RM

Prior to executing the construction process, it was necessary to identify an appropriate implementation technique of this process. The Case study is the most commonly applied method in information systems (Yin, 2018). This study conducted a single, exploratory, descriptive, and in-depth case study to builds a business RM from a qualitative Case Study strategy, which requires rigorous techniques to produce quality findings as suggested by (Yin, 2018) who identified multiple phases to conduct the case study including, designing a case study protocol, determining the research questions, selecting the case, determining data collection and analysis techniques, preparing and collecting data, evaluating and analyzing data, and writing the report.

Case Study protocol :A case study protocol precedes the definition of the questions and is aimed to represent the instrument, procedures and general rules. Table 4 demonstrates seven sections of protocol design, while Appedix 1 details on the protocol document elements at which section 1 expresses the objective of the study, Section 2 explains the case procedures, Section 3 lists the formulated questions stemming from the objective, Section 4 represents data collection matrix suggested by (Ritchie et al., 2003) including, the data collection techniques, tools and evidences, while Section 5, 6, and 7, respectively demonstrate the preliminary, vision, and BA templates of TOGAF architectural components.

Table 4 *THE PROTOCOL DESIGN OF THE CASE STUDY*

Section #	Title	Content
1)	Overview	A statement of the overall aims of the current study.
2)	Case Study procedures	How to gain access, capture data, time plan for data collection, etc. for a case.
3)	Case Study questions	Formulation of specific questions relevant to the literature and theory.
4)	Data collection matrix	A matrix (table) for collected evidences corresponding to the study questions.
5)	Template (I)	Architectural preliminary document template.
6)	Template (II)	Architectural vision document template.
7)	Template (III)	Business architecture document template.

The case selection :Suggested by (Ritchie et al., 2003), the "criterion case" type was selected because it meets predetermined criterions. Advocated by (Yin, 2018), the process of case selection should be guided by the literature and that cases should be easy and willing subjects for conduction in a limited time. Further criterions were considered at which amongst the 50 architecture practicing enterprises in Bahrain (Shakir, 2002), one single enterprise was found matching criterions. In other words, to study the business side of AEC/Construction enterprises, the case should be located in Bahrain and a A-Grade to comply with the international architectural work standards, implying that it follows standardized business functions and processes. Moreover, the case fulfilled the time limitation criterion by fast responding to the interview request. Since its starting in 1990 with 35 staff members, Comp1 (original name is hidden) acted as an international architectural and engineering consultancy enterprise, provided services of architectural engineering design, engineering, technology, and business. Comp1 is licensed to practice in architecture as an A- Grade approved by the Bahraini committee for organizing the practice of engineering.

Data collection of core components :Data collection espoused two method triangulations; primary and secondary techniques of data collection that encompass structured interviews and document analysis, respectively. Method triangulation was emphasized to gain in depth data from the case study, to ensure rigorousness, to overcome the potential bias, and to guarantee the validity and reliability of the study (Yin, 2018). The sample size was determined based on (Yin, 2018) who recommends three to five interviewees per case study. Thus, three structured interview sessions and two telephone conversations were conducted with six participants; the chief architect, the managing director, the deputy general manager and three architects and drafters. Each session took two hours and each phone conversations took fifteen minutes. Interviewees were informed of the conversation recording procedure and consequent note taking at the starting of the interview (Yin, 2018). The document analysis entailed analysing the case web pages, presentations, brochures, strategic plan, and architecture projects. Collected datasets were manually coded according to the matrix predetermined themes Appendix 1 (Template I, II, III) in MS excel. Thematic analysis was conducted following the insights and suggestions of (Benayat, 2023).

Demonstrated in Section 3 of Appendix 1, one main question and 4 stemming sub-questions were formulated resulting from the study objective and contributed to constructing the business RM. The main question was how to develop a human interpretable business reference model of the Criterion Case? Q1.1 stemmed from it to inquire about the core elements that constitute a business reference model of the Case. The question aimed to find the variables of the research study. These included the actors, roles of the actors, the business units at which actors perform their roles, the business functions of what actors in the units perform, the process of performance carried out within the functions, and the services the whole architecture enterprise deliver to the customers. Q1.2 inquired about the pertaining phases of the architectural project of the case. Q1.3 inquired about the core components which TOGAF can provide and how those components would address the baseline state of the Case. Q1.4 inquired about how ArchiMate modelling language would generate a graphical model that addresses the baseline state of the Case. Q1.5 demonstrated the evaluation process based on DSRM.

Testing of the Case Study design :The use of reliability, validity, and triangulation started to gain popularity in the qualitative research paradigm, so testing as a way of information elicitation (reliability) is equal to quality in qualitative research which entails persuading audiences of the sound research findings and examining trustworthiness (Yin, 2018). Consequently, three quality tests were performed during the phases of the undertaken case study. Consequently, External validity was claimed- due to scarcity of studies about Bahraini AEC/Construction- with one single case. Since the study's objective is bounded with the AEC/construction sector, domestic enterprises were selected because they contribute to the country's sustainable economic development that is targeted by employment creation, income generation, and other physical and social goals. Moreover, A-Grade enterprises permanently have higher activity levels with other industries, which in turn leads to higher growth expectations, have stronger track records of project operating efficiency to the required quality standards with less cost, time overrun, and working capital management capacity. In addition, fast response is a crucial part of case study design as the more the target case is welcoming and dedicated, the more they cooperate. During the data collection process, the personnel were entirely available to answer structured interview questions showing high level of decency during telephone calls. On the other hand, construct validity was claimed by linking data collection questions to research questions and by applying a chain of evidence (Triangulation). Two primary sources of evidence were enforced including structured interviews and telephone interviews, along with two secondary sources including organizational structure and website documentary material. However, during the composition stage of review, the deputy manager reviewed the draft case study report. Finally, reliability was claimed

through the generation of BA templates to document the data collection procedures. Thus, prior to data analysis, collected interviews data, memos, and notes were transcribed, organized and protected. The enterprise was assigned a code at which collected data was saved in a secure and confidential file, which was created to back up and store hard and soft electronic transcripts at various stages.

RESULTS AND DISCUSSION

This section comments on and explains the demonstration, evaluation , and communication phases of the DSR method all along with a comprehensive discussion on the empirical findings.

Demonstration

The analysis method framework is a matrix based analytic method that performs analysis by allowing classification and organization of datasets into themes, categories, and concepts and identifies similarities and differences between participants (Benayat, 2023). The framework involves a four-step process namely, data indexing, data sorting, data description, and summarizing or synthesising. First, data coding index was assigned to each concept identified during interviews. Indexing of the dataset took the format of A.0.0.0.0 referring to the business strategic objectives (SO), as demonstrated in section 6 of the protocol document in appendix (1). Then, subheadings were given to the concepts under each main heading, identified as A.1.0, 0.0, referring to the BSO id#, etc. Then, giving the next concept the index of A.0.1.0.0 with sub-concepts identified as A.0.2.0.0, etc. We finally recorded numerical codes in the transcripts. Second, data was sorted to assemble text of similar content. Third, data within a category was examined to identify the range of content and dimensions within the theme. Fourth, each theme was created on a thematic chart and participants were allocated a row in the matrix.

The Business Strategic Objectives (SO)

Resulting from interviews with the managing director, seven prioritized business strategic objectives (SO1-SO7) were collected. Table 5 demonstrates the SOs as determined by the managing director. Table 6, however, demonstrates the SOs in accordance with the collected business units (U) and business functions (F).

Table 5 *THE BUSINESS STRATEGIC OBJECTIVES (SO)*

Business Objective id #	Business Objectives
so 01	Become a full Private enterprise
so 02	Service Private sector
so 03	Produce landmark projects
so 04	Target the upper-market segment
so 05	Seek quality service
so 06	Collect full fees from customers at earlier
so 07	Recruit less no. of highly qualified staff

The business units (U) : The deputy manager was asked for a static organizational structure of the case as depicted in Figure 4. Units were collected as in Table 6 and 7 comprising 15 physical and non-physical units (U01- U15). To quantify and organize the findings, units were assigned id #, names, and description. However, some units were virtual. Compared to Figure 2, the IT department (U15) was not physically apparent as it was managed by the general deputy manager. Noticeably, the chief architect was assigned to the managing director role. Roles were found in different locations.

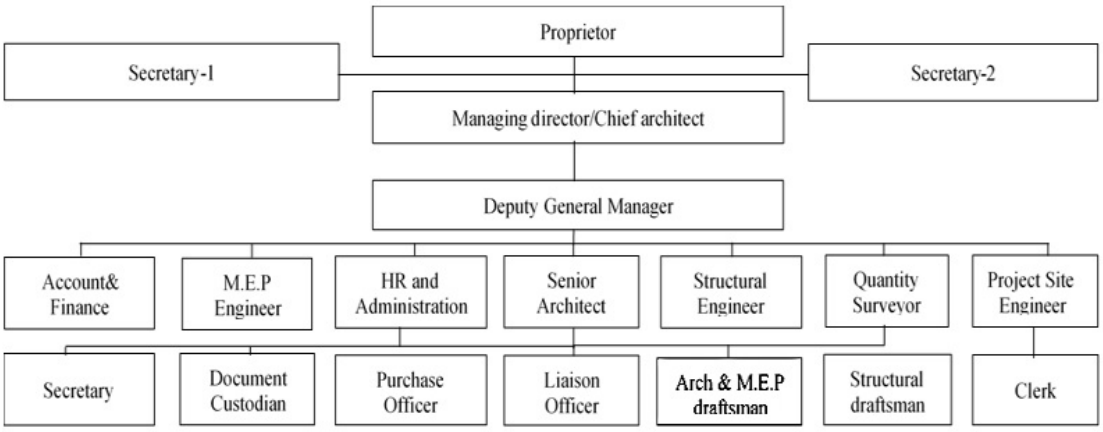

Figure 4 *The Business organizational structure*

Table 6 *THE BUSINESS UNITS (U)*

Unit id #	Unit Name	Unit description	Unit Parent	Actor id #	Actor/Role
U01	Proprietor or Managing Director	Setting the tone for a company's management and operations	Management	A/R 01	Managing Director
U02	General Management	Running of company's management and operations	Management	A/R 02	General Manager
U03	Chief Architecture	Designing focusing on all project activities	Architecting	A/R 03	Chief Architect
Uo4	Senior/Junior Architecture	Design focus of specific project activities	Architecting	A/R 04	Senior/Junior Architect
U05	Drafting	Sketching detailed technical drawings for buildings by a software	Engineering	A/R 05	Draftsman
U06	Structural Engineering	Performing of stability and strength of built structures for buildings	Engineering	A/R 06	Structural Engineer
U07	Mechanical (AC, Plumbing, Drainage & Thermal insulation)	Performing HVAC, piping and water supply	Engineering	A/R 07	Mechanical Engineer
U08	Electrical Engineering	Surveying the site and managing the design of electrical systems	Engineering	A/R 08	Electrical Engineer
U09	Quantity Surveying	Performing construction costs and contracts	Quantity Surveying	A/R 09	Quantity Surveyor

Table 7 *CONT...*

Unit id #	Unit Name	Unit description	Unit Parent	Actor id#	Actor/Role
U10	Tendering	Working through tender process and const. & maintenance contracts	Tendering & Contract	A/R 10	Quantity Surveyor
U11	Municipal Liaison	Activating a mediation process between the office and the municipality	Tendering & Contract	A/R 11	Municipal Liaison officer
U12	Project Site Engineering	Setting out the works in accordance with drawings and specification	Supervision	A/R 12	Project Site Engineer
U13	Accounting & Finance	Control of company's financial operations and employee relations	Supporting	A/R 13	Accounting Manager
U14	HR & Administration	Management of human resources within the organization	Supporting	A/R 14	HR & Admin Manager
U15	IT	Installation, execution, upgrading and maintenance of software apps	Supporting (Virtual)	A/R 15	General Deputy Manager

The business actors/roles (A/R) & the business functions (F) : Table 8 and 9 lists the available actors (A/R 01- A/R 15) at which they were assigned id #, names, and description. However, a business function (F) is a grouping of internal behavior based on a certain criterion which supports the business goals (Dietz et al., 2013). Six functions (F01-F06) were collected as demonstrated in Table 10.

Table 8 *THE BUSINESS ACTORS/ROLES (A/R)*

Actor id #	Actor Role name	Actor/Role description
A/R 01	Managing Director	"- Determines scope of work - E stimates initial cost (With Concept/without Concept) - Writes an agreement (Contract) with a Client"
A/R 02	General Manager	"- Determines scope of work - E stimates initial cost (with concept/Without concept) - Writes an agreement (Contract) with a client"
A/R 03	Chief Architect	"- Identifies client's business case and strategic brief and other project requirements. - Develops project objectives, project budget, and project brief. Undertakes feasibility studies and reviews of site inform ation"
A/R 04	Senior/Junior Architect	"- Prepares concept design, including outline proposals for structural design, building service system - Outlines specifications and preliminary cost information - Approves alterations to brief and issue final project brief."
A/R 05	Draftsman	"- Prepares and specifies technical CAD drawings, materials, and procedures assigned by architects. - Uses calculators, tables, and technical handbooks"
A/R 06	Structural Engineer	"- Checks the structural performance of a large part of the built environment - R equires expertise in strength of materials"
A/R 07	Mechanical Engineer	"- Designs heating ventilation and air conditioning (HVAC), plumbing, and rain gutter systems - Designs plumbing designs including, design specifications for simple active fire protection system"

Table 9 *CONT...*

Actor id #	Actor Role name	Actor/Role description
A/R 08	Electrical Engineer	"- Monitors the building's power distribution, telecommunication, fire alarm, signalization, lightning protection and control systems, and lighting systems"
A/R 09	Quantity Surveyor	"- Prepares cost estimates, tender documents including bills of quantities up to award of work. - Certifies contractor's onthly valuations, variations, and finalization of account"
A/R 10	Quantity Surveyor	- Selects contractors that will construct the works.
A/R 11	Municipal Liaison officer	- Handles the tendering Process.
A/R 12	Project Site Engineer	- Plans, monitors, and controls project implementation quality control and contract administration
A/R 13	Accounting Manager	- Manages cash flow and ensure sufficient funds available for day to day paym ents
A/R 14	HR & Admin Manager	- Recruits staff, trains, record's keeping, compensates performs benefits, and provides insurance
A/R 15	General Deputy Manager	- Provides IT solutions including, software, hardware, networking services

Table 10 *THE BUSINESS FUNCTIONS (F)*

Fun id#	Function Name	Unit id #	Function Description	Strategic Objective id#
F01	Managing	U01, U02	Budgeting, consultancy, client & engineers' meetings	SO 01, SO 02, SO 03
F02	Architecting	U03, U04	Designing of structure, budget & requirements.	SO 03-SO 07
F03	Engineering	U05,U06,U07,U08,U09	Preforming MEP and Quantity Surveying	SO 03, SO 07
F04	Tendering & bidding	U10, U11	Tendering and biddings awarding	SO 03, SO 07
F05	Supervising	U12	Supervision of construction projects	SO 03, so 07
F06	Supporting	U13, U14, U15	Accounting & Finance. HR & Administration and IT	SO 03, SO 07

The business processes (P) : A business process (P) is a collection of sequence of internal behaviour which produce a predefined collection of functions. Further, a process consists of a chain of activities that are executed in a certain sequence, at which every activity is part of a business function (Dietz et al., 2013). Table 11 demonstrates 10 collected processes (P01-P10) cross-mapped with the business functions and the business services.

Table 11 *THE BUSINESS PROCESSES (P)*

Process id#	Process Name	Process Description	Service id#	Supplier	Consumer
P01	Perform scope of work	Define description of work and WBS and scope of services between client and architect	S01	F01	Client
P02	Activate agreement	Estimate cost and write agreement of work	S01	F01	Client
P03	Produce conceptual design	Prepare site plan	S02	F02	Client
P04	Produce schematic design	Develop a master plan	S02	F02	Client
P05	Produce design development	Develop perspectives, drawings, prelim structural calculation, design of M.E.P, and load calculation	S02	F03	Client
P06	Prepare application of building permit	Upload drawings to Municipality and preparation of invoice	S02	F04	Client
P07	Perform detailed design development	Develop complete Construction Drawings and invoice	S02	F04	Client
P08	Prepare tender documents	Prepare tenders (offers) and design specifications	S03	F04	Client
P09	Award tenders & contracts	Analyze tender documents and select contractors based on BOQ and schedule	S03	F04	Client
P10	Supervise and manage project sites	Plan, monitor, control project, quality, and manage sites	S04	F05, F06	Client

The business services (S) : Services are the value adding entities delivered by an enterprise to its environment (Dietz et al., 2013). Demonstrated in Table 12, four external services (S01- S04) were collected.

Table 12 *THE BUSINESS SERVICES (S)*

Service id #	Service Name	Service Description	Function id#
S01	Project Planning	Strategic Definition and Preparation and Brief	F01
S02	Architectural Design Provision	Concept Design, Schematic Design, Design Development, Application of Building Permit and Detailed Design	F02,F03
S03	Tendering & Contract Administration	Tender Doc preparation & Contract warding	F04
S04	Project Management, Supervision & Completion	Project Site management & project hand over	F05, F06

The constructed business RM model : A modeling language is defined by its syntax, semantics, and notation which provide the desired modeling primitives in order to build the model (Hinkelmann et al., 2016). Based on the findings, a business RM of the AEC/construction sector in Bahrain entails 7 objectives, 15 actors working in 15 distinctive units, 4 architectural related services delivered to the clients, 6 functions worked out based on the workers disciplines, and 10 processes of activities. Figure 5 depicts, in ArchiMate, the detailed business RM of the Comp1 which represents the abstracted model for the entire AEC/construction industry, while Figure 6 provides an illustrative task example.

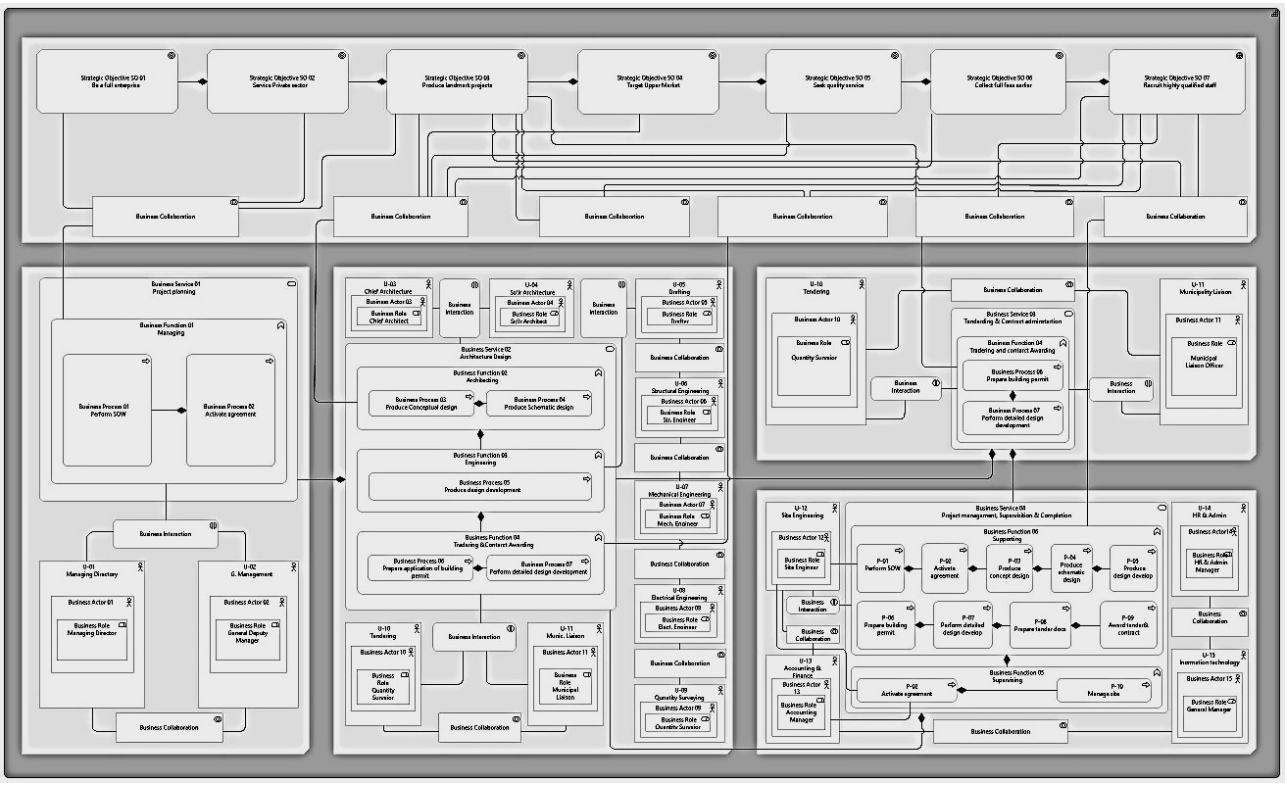

Figure 5 *The detailed business RM of Comp1*

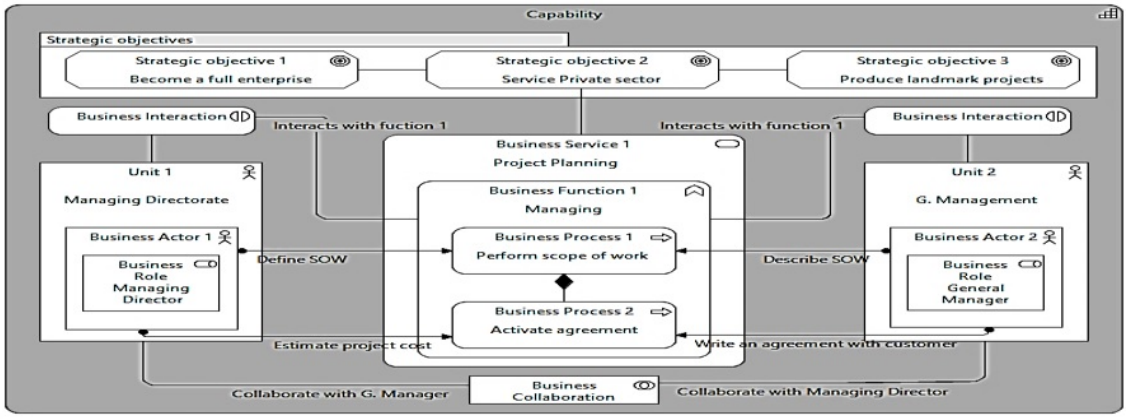

Figure 6 *An illustrative task example of the business RM of Comp1*

Evaluation and Communication

A reference model is subject to evaluation based on two criteria including, theoretical soundness and the modelling taxonomy. Through two rounds of Delphi evaluation, 11 quality criterions of the constructed model were evaluated to collect experts' opinions (de Bruin & Rosemann, 2007). According to (Skinner et al., 2015), the selection of the expert panel and the number of rounds form the success factors of Delphi technique. Therefore, in 2 rounds, 4 experts from the Bahraini information & eGovernment authority and 2 personnel of Comp1 were found suitable to form the evaluation. Accordingly, based on a 5-point likert scale (Strongly Agree=5 - Strongly Disagree=1) questionnaire, the four expert's responses were then collected, grouped, and synthesized and the final responses were averaged towards the conclusion. Table 13 lists the quality parameters/criterions for the evaluation of RM as suggested by (Elangovan & Rajendran, 2015) along with the responses of the 2 rounds per expert. The constructed model has achieved an average of 73% which is a successful percentage on the appropriateness of the model.

Communication refers to the importance and effectiveness of the artifact to the researcher at which the identified problem and the proposed solution should be documented for publication excluding any restricted or sensitive information of the enterprise. All aspects of the problem and the designed artifact are communicated to the relevant stakeholders and academic audience throughout this paper publication.

Table 13 *THE QUALITY PARAMETERS FOR THE METHOD AND BUSINESS RM EVALUATION*

	Round 1					Round 2					Total Rounds Avg				
Criterions	S.Agree	Agree	Neutral	Disagree	S.Disagree]	S. Agree	Agree	Neutral	Disagree	S.Disagree	S.Agree	Agree	Neutral	Disagree	S. Disagree
Clarity	50%	50%	0%	0%	0%	75%	25%	0%	0%	0%	63%	38%l	0%	0%	0%
Simplicity	50%	50%	0%	0%	0%	50%	50%	0%	0%	0%	50%	50%	0%	0%	0%
Expressiveness	0%	100%	0%	0%	0%	75%	25%	0%	0%	0%	38%	63%	0%	0%	0%
Minimality	50%	0%	0%	50%	0%	50%	0%	0%	25%	25%	50%	0%	0%	38%	13%
Completeness	50%	50%	0%	0%	0%	25%	75%	0%	0%	0%	38%	63%	0%	0%	0%
Accuracy	50%	50%	0%	0%	0%	50%	50%	0%	0%	0%	50%	50%	0%	0%	0%
Abstraction	50%	0%	0%	50%	0%	50%	0%	0%	50%	0%	50%	0%	0%	50%	0%
Consstercy	50%	0%	25%	25%	0%	50%	0%	25%	25%	0%	50%	0%	25%	25%	0%
Unambiguty	50%	0%	25%	25%	0%	50%	0%	25%	25%	0%	50%	0%	25%	25%	0%
Testability	100%	0%	0%	0%	0%	75%	25%	0%	0%	0%	88%	13%	0%	0%	0%
Reproduibiity	0%	0%	0%	75%	25%	0%	0%	0%	100%	0%	0%	0%	0%	88%	13%

CONCLUSION

The AEC/Construction's ecosystem is yet not well defined and never reached a common agreement among its business domain. To enrich the sector with the latest ICT systems, developers and vendors find it troublesome to identify the ICT's maturity levels, gaps, duplicative levels, and future investments. Following the DSR of research design method, this study provided a method to construct a business RM for the AEC/construction sector that is capable to provide a human graphical interpretation model from the cross-agency analysis of the structural elements and the functional operations. The business RM– through a Case Study approach- is constructed by adapting EA theory, performing a customization to TOGAF, and modeling using ArchiMate, and is evaluated through a Delphi two rounded Questionnaires. The objective of the study is successfully met as the ecosystem of the sector was explored, the

appropriateness of the method based DSR and Case Study for data collection was investigated, and the Delphi based evaluation of the business RM technique based on 11 criterions to generate 73% of usability .

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APPENDIX-1: THE PROTOCOL DOCUMENT OF THE CASE STUDY

1	**Case Study**	The case study strategy aims to select, collect, and analyse the business process of the selected case.
2	**Case Study Protocol**	**Step #** / **Steps** 1 — Execute case study strategy and select it based on the criterion. 2 — Select a Case based on the criterion (Located in Bahrain, International, A-Grade, Fast response). 3 — Request for a first visit, get positive response, perform meeting, & submit official interview letter. 4 — Execute TOGAF ADM, Record collected data manually, Re-Record collected data in a database 5 — Modify data collection procedures if necessary (request documentary data). 6 — Verify the collected data synchronously, Develop, analyze, and test validity of the case.
3	**Case study Questions**	**Q1. How to develop a human interpretable business reference model of the Criterion Case?** Q1.1 — What are the core elements that constitute a business reference model of the Case? Q1.2 — What are the pertaining TOGAF phases to execute the construction method? Q1.3 — What are the TOGAF core components to address the baseline business process of the Case? Q1.4 — How does ArchiMate generate a graphical model that addresses the baseline business process? Q1.5 — How to evaluate the business RM?

Figure 7 *The Protocol Document of the Case Study*

4	**Data collection matrix**	**Data collection techniques and tools** **Q** / **Data coll_tech.** / **Methods** / **Evidence** / **Rationale** Q 1.1 — Second Source — - Literature review — LR — Investigate BR models. Q 1.2, 1.3, 1.4 — Primary Source — - Structured interview - Tele interview — Template I, II, III — - Align the Case with TOGAF. - Define the baseline business RM. Q 1.2, 1.3, 1.4 — Second Source — - Literature review — LR — - Define the baseline business RM. Q1.5 — Primary Source — - Delphi Technique — Questionnaire — - Evaluate the business RM.
5	**Temp (I)**	**D. Architectural scope** 1 — Architecture stakeholders — Researcher authors, the owner, CEO, architects, and engineers. 2 — A statement of requirements — Not Applicable 3 — The architecture goals and objs. — Develop a business architecture of the case
6	**Temp (II)**	**Architectural development steps** Establish the project Identify stakeholders, concerns, and business requirements Confirm and elaborate business goals, evaluate business capabilities, and Assess readiness for transformation

Figure 8 *Cont...*

7	**Template (III)**	**A. Organizational Strategic Objectives** Bus obj-id | Business Objectives | IT objectives-id | IT objectives **B. Organizational Structure and Units & Actor/Roles** Unit-id | Unit Name | Unit Parent | Unit Description | Actor/Role-id | Actor/Role **C. Business Processes** Process - id | Process-N | Pro_ Description | Service-id | Suppl of I/P | Consumer of O/P **D. Business Functions** Unit-id | Function-id | Function Name | description | classification | Strategic Obj - id **E. Functional Decomposition** Unit-id | Sub- Function-id | Sub-Function | Sub- Function Description **F. Business Services** Service-id | Service Name | Serv description | Function- id

Figure 9 *Cont...*