A qualitative study for establishing the conditions for the successful implementation of public private partnerships in research reactor project in newcomer countries

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Abstract: The UAE is currently developing a peaceful nuclear energy program as part of its low carbon energy strategy to meet future energy demands. Research of nuclear energy technologies is required to support nuclear energy generation projects and maximize their performance. Research of this type will require building and operating a research reactor (RR), a costly undertaking in most circumstances. Collaboration between government and private parties through public private partnerships (PPP) can maximize the benefits expected from the adoption of a RR project. The aim of this research is to establish the conditions for developing a RR project for newcomer countries, with the UAE taken as a case study, through the utilisation of public private partnerships (PPP). The results of this study were arrived at through the use of semi-structured interviews conducted with 10 experts in the field of research reactors, using grounded theory method. Ineffective project initiation work was found to be the main causal condition influencing the success of PPPs in research reactors, governmental and political interventions were the intervening conditions, the local/regional justification and viability were the contextual conditions.

Keywords: Public Private Partnerships (PPP); Research Reactors (RR); Grounded Theory (GT).

1. Introduction

The United Arab Emirates (UAE) is currently developing a peaceful nuclear energy program to respond to future energy demands. The UAE is encouraged to pursue research activities to compliment the energy generation project. Such research will require the development of a research reactor project, which will not only benefit research to support nuclear power plant operations, but also all industries identified in the UAE's growth strategies. These industries include transportation, health services, construction, petro chemicals, technical colleges, and R&D facilities [1,2].

The primary uses of research reactors are mainly focused on two areas. The first area is training and education in areas such as reactor physics and engineering, operator training, radiation shielding, and nuclear analytical methods. The second area relates to products and services for the society, such as radioisotope production for medical services, Boron capture therapy, neutron imaging, geochronology, and material and fuel testing [1,3].

A research reactor requires a heavy, upfront investment and poses high risks to governments due to potential lack of skills, experience, and high operation and maintenance expenses [3]. However, if utilized properly, a research reactor could become a valuable player in the long-term economic growth of the country, and it is here where the private sector can play a vital role. The collaboration between governments and private parties through public private partnerships (PPP) can maximize the benefits expected from the adoption of a research reactor project [4,5]. PPPs are "long-term relationships involving the private sector in the provision of public services that in many cases had previously been entirely the responsibility of the public sector" [6, p. 4]. PPPs have become very popular mechanisms for procuring public works around the globe due to their high success rate in bringing quality, efficiency, innovation, funds, experience, and most importantly, risk sharing to developed projects [4]. Therefore, PPPs are expected to maximize the benefits sought after in the adoption of a research reactor project.

The PPP terminology was first introduced in the UK in 1997 by the labour government. Prior to this, other arrangements of similar collaborative form of engaging the private sector fell within the private finance initiative (PFI). The PFI was launched in 1992 and was known as a project finance mechanism by the UK's conservative government [6].

PPPs are expected to improve the utilization of research reactors through the efficiency they bring to the developed project. Goldman et al. [7, p. 18] in their study 'Progress in Promoting Research Reactor Coalitions' stated that in order to improve the utilization of research reactors, "Public-private partnerships need to be pursued." This study will highlight the benefits of sharing risks and, equally, the financial benefits between the public and private sectors to maximize the outcome of a research reactor, which include the production of the isotopes needed for medical and industrial purposes, the neutron beam research for non-destructive material testing, and the research and training procedures for nuclear power generation staff and research and development (R & D) researchers [8].

This research, also, takes the initiative to highlight for the authorities the particular conditions that impact the success of a research reactor to improve the success rate of developing it under the PPP mechanism. Previous experiences have demonstrated that research reactors would most likely require some sort of public funding support throughout their lifetime [10]. Such funding includes planning cost, bid process, construction, commissioning and decommissioning, operation, disposal of spent fuel and radioactive waste, and facility maintenance. Therefore, the financial commitment of the public party is likely to run for decades and will require meticulous planning, careful assessment, and viable funding alternatives before the commencement of the project [5,10].

Therefore, the rationale of this study is to establish the conditions for developing a research reactor project for newcomers through the utilisation of public private partnerships, which was never empirically tested before.

This study is divided into six sections. Section two presents a literature on the current discussion on research reactors and PPPs. Section three presents the methodology adopted in this study. Section four presents analysis of the grounded theory findings. Section five presents the discussion of the results. And, section six presents the conclusions and limitations of the study.

2. Research reactors

Research reactors (RRs) have been the main contributors to innovation in nuclear science and technology for over 60 years. The research that RRs facilitate has been the centrepiece for the advancements seen in radioisotopes production and nuclear medicine, neutron beam application, computer code validation, material characterization, and nuclear power generation [8].

A research reactor project is a major undertaking that requires meticulous preparation and investment planning. The project must follow strict safeguards and will require full awareness of nuclear safety, security, and control of nuclear materials handling. The decision to undertake a research reactor project should be based on identified outcomes of adopting such a complex and sensitive project. This also includes compliance to the international treaties and conventions governing safety, security, and safeguards for nuclear programs and facilities. The government, to discharge such responsibilities, must provide a sustainable infrastructure that provides financial, legal, governmental, technical, industrial, and administrative support for the life cycle of the research reactor project [3,9].

Governments can share the cost and risks with the private sector to ensure the efficient and effective operation of research reactor projects. However, this will require a commitment to be part of all stages of the project. Therefore, before inviting the private parties to be part of the project's development consortium, governments must first have in place the planning and funding mechanisms for regulating, operating, decommissioning, and management of spent fuel and waste. Research reactors also require supporting infrastructure to enable them to work efficiently. This includes all activities required for the development and operation of the RR, such as physical plants and equipment associated with the RR, the logistics of handling nuclear materials, and the management of spent fuel and radioactive waste. It also includes the regulatory framework and the financial and human resources needed to ensure safety, security, and the efficient and safe development and utilisation of the RR throughout the life cycle of the reactor. There must be a solid justification for adopting a research reactor project based on national or regional needs for its services, the alternatives available, and the financial and human resources available [9, 10].

Research into the field of research reactors nowadays is centred on reducing cost while maximizing the utilisation of such facilities. The reason for this is that the majority of research reactors in operation today are either near retirement or are underutilised. Furthermore, the demand on research reactors is ever increasing, forcing the decision makers to look for innovative ideas to reduce the cost while supplying the market with the required services. There are many factors that affect the success of research reactor projects. Such factors include the availability of required infrastructure, quality assurance, and the level of participation of local researchers and businesses [5]. The infrastructure that is annexed to the research reactor plays a significant role in the maximization of the utilisation of the reactor. The successful processing of the products and services of research reactors requires a rigorous and innovative R&D process to convince the customers of the value of such services and products. Qualified personnel and ample R&D expenditure are preconditions for the success of research reactors [5].

There is a significant threat to research reactors in the form of the plan to minimise the use of highly enriched Uranium (HEU) in research reactors for security reasons. There are already other alternatives to certain applications of research reactors such as the isotope production through accelerators. However, the commercial viability of using accelerators still has not achieved. Pillai, Dash and Knapp [11] stressed the advantages of using research reactors over the accelerators option by stating that research reactor applications are inexpensive and realistic among other advantages. However, in light of the requirement for the security measures, the commercial viability might not be a hindrance to resorting to other alternatives.

According to [5] the threat of these technologies to RR viability is still minimal since their associated capital and operating costs are high compared to RRs. Furthermore, the new technologies have not been used for continuous production of radioisotopes, and cannot cater for certain applications of research reactors, e.g. training, etc. Still, any plans for future RRs must consider the potential long-term threat of such alternatives, but this should not be a hindrance for PPP consideration .

3. Methodology

This study is the last phase of a study for establishing the CSF for PPPs in research reactor project in the UAE. The full study employed a mixed methods research approach. The objectives of the study were focused on the formation of a generic PPP framework, the success factors of collaborations between the public and private sectors in developing projects in the

UAE, and the success factors for a research reactor project. The first two objectives were already achieved in other studies by the researcher [12,13].

A qualitative methodology was used in this study for data collection and analysis for the establishment of the conditions pertaining to the successful implementation of PPP in a research reactor. "Conditions are sets of events or happenings that create the situations, issues, and problems pertaining to a phenomenon and, to a certain extent, explain why and how persons or groups respond in certain ways" [14, p. 130]. There are different types of conditions, and they include causal, intervening, and contextual conditions. Causal conditions are the events or happenings that directly affect the phenomena. Intervening conditions are the events that alter the influence of causal conditions on the phenomena. Finally, contextual conditions are the ones that arise from unforeseen circumstances [14].

The instrument used was grounded theory. First, a questionnaire that guided the design of the interview questions was conducted. Next, the in-depth semi-structured questions were developed. Last, the grounded theory and all its steps - open, axial, selective coding, and substantive theory were conducted.

A questionnaire was used to guide the formation of the semi-structured interview questions since the questions for grounded theory cannot be based on previous theoretical scales. The purposive sampling process utilised some of the participants at a workshop organized by IAEA entitled "Training Workshop on Specific Considerations and Milestones for Research Reactors Project." 15 participants returned completed questionnaires. The analysis of the collected questionnaires proved their value in the finalization of the interview questions.

The selection criteria for the interviews focused on individuals who are in senior positions in research reactor projects within the leading countries in this industry. Therefore, the technique used for the initial identification of the subjects was purposive sampling. Snowball sampling also was used for the interviews due to the limited number of subjects identified since PPP practice in RR is relatively new.

TABLE 1: Interviewees background information

Expert	Designation	Sector	Experience	Country
1	Professor	Public	20+	Korea
2	Professor	Public	20+	USA
3	CEO	Private	20+	Denmark
4	Professor	Private	20+	Argentina
5	Professor	Public	10+	Korea
6	Professor	Private	20+	France
7	Professor	Public	10+	USA
8	Professor	Public	30+	Argentina
9	Professor	Public	30+	France
10	Professor	Public	30+	Turkey

The total number of conducted interviews was ten interviews. Information about the experts is provided in Table 1. This figure is assumed to be sufficient to render the research viable. Most studies conducted through the grounded theory approach, as highlighted by Mason [15], start with a minimum number of interviews and then follow them by a second round of interviews based on gaps found in data. Saturation was present from the beginning and around the sixth interview the data analysis began to indicate repetitive patterns and no new themes were found. Therefore, ten interviews were deemed sufficient for this study.

The grounded theory approach was chosen for data collection and analysis of semi structured interviews whose practice involves continual data collection and analysis through three coding stages: open coding, axial coding, and selective coding; through these the linkage between all elements is identified and subsequently leads to the construction of the theory. The most widely used software in qualitative data analysis is NVIVO. This software is of particular importance to grounded theory, as the key functions of NVIVO allow for the open coding, axial coding, and hyperlinks to other forms of data such as audio, video, photographs. The software program was developed to encourage researchers to collect data and analyze it simultaneously, not to wait until all data is collected [16].

In grounded theory, data collection and analysis are inter-related. The theory develops through the constant comparison of the constructed elements of theory and the new sets of data collected in response to identified gaps in existing data. Such comparison is continued until the new data confirms the previous findings or until no further themes or relationships emerge from the new data, leading the research to reach a state of theoretical saturation; a point at which a formal theory can be proposed [17].

3. Results and analysis

Ten interviews were consecutively conducted with senior researchers and practitioners in the research reactors industry, until sufficient data was collected. The semi-structured interviews were transcribed and imported into the NVIVO software.

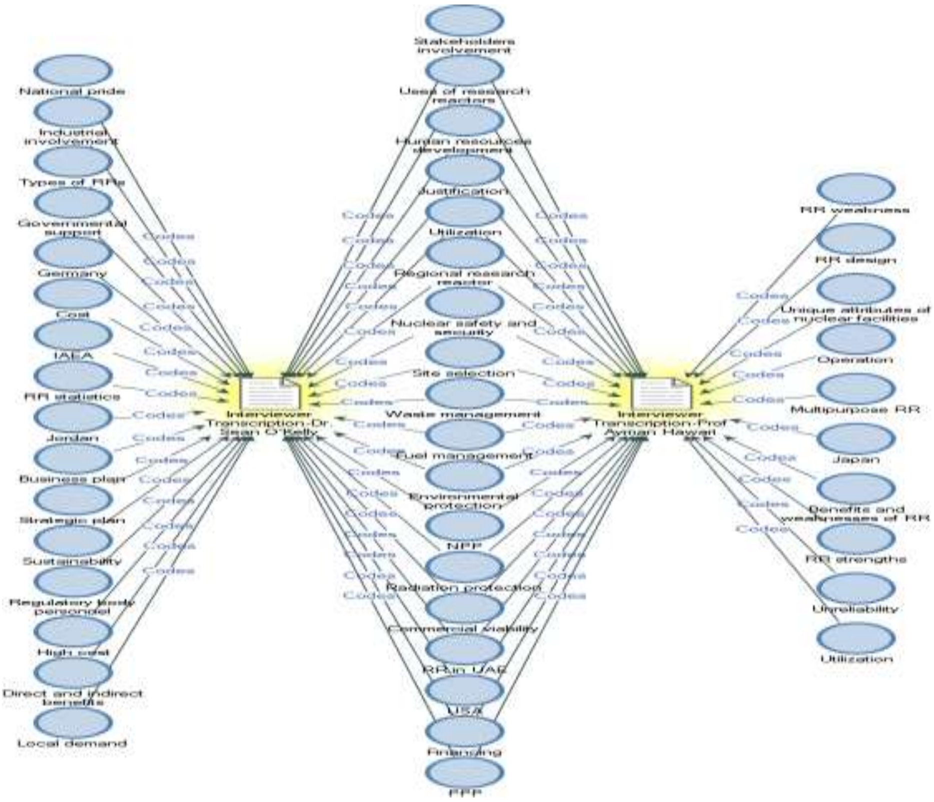

FIGURE 1: Comparison process between interviews for theoretical coding

In the open coding process, the initial step was to create nodes for storing the statements of the interviewees according to the topic. The next step was to compare the statements for theoretical coding (*FIG. 1*). The concepts that emerged from the constant comparison were outlined in an open coding template to enable the formation of a category that best describes these concepts. Then each category was defined in terms of properties to enable the commencement of the axial coding process.

During the process of the axial coding paradigm, underutilisation of research reactors was identified as the core category and was identified as a primary reason for failures in research reactors; it is also a deterrent of future partnerships between governments and the private sector (figure 4). The rest of the coding paradigm was identified as follows: Causal conditions (ineffective project initiation work), Context (local and regional considerations), Intervening conditions (government and political interventions), Strategies (justification process), and Consequences (Local demand justifications, viability to alternatives, partnership potential).

Each category and subcategory of the coding paradigm is to be evaluated individually, confirming its relationship to the core category. The paradigm model was checked again after reviewing more data, and further interviews were conducted to confirm its structure and the relationships of its categories. Therefore, all categories and subcategories in the model were rechecked for their relationships with the core category. The validity of the relationships in the coding paradigm required the establishment of propositions to test the relationship between the core category and other categories and subcategories. [14,18].

3.1. Causal conditions

There are many important conditions to be considered in the project initiation work for the research reactor project that affects directly the utilisation of such reactors. Insufficient project initiation work and its properties influence the level of utilisation the research reactor project can have. These conditions are related to the stakeholders, life-cycle financing and funding, nuclear safety and security, site selection, fuel and waste management, environmental and radiation protection, human resources development, and the regulatory body. These properties shape, individually or collectively, the outcomes of research reactors and therefore create the value that private investors could be attracted to. For instance, not having a sustainable human resources development plan will directly affect the utilisation of the research reactor and therefore could pose a viable threat that operations could be interrupted during the lifecycle of the project. Another example is the early involvement of users in the design and finance of the project. This is a multidimensional factor that is focussed on the impact of a group of properties. Early identification of users leads to designing the reactor according to their needs so that the required uses are secured, in addition to the establishment of the actual local demand. This is in line with IAEA recommendations, "The users and other stakeholders of the research reactor are essential to its long term viability, and should be closely involved in the specification of the research reactor capabilities, as well as consulted on important design decisions" [5, p. 37]. This will enable the development of the project according to an actual economic feasibility, and will offer a diversified stream of funding by engaging the users into a partnership relationship.

3.2. Intervening conditions

The intervening conditions are those conditions that alter or mitigate the influence of causal conditions [14]. Government and political interventions were identified as the intervening conditions that alter the outcomes of project initiation work, which, when not done properly or are not considered when making the decision for developing the research reactor project, influence significantly the operations of research reactors. The investors or users will only be attracted to the project if there is a clear financial reward for their participation, and having a project that was commissioned based on political decisions related to national pride or a local politics campaign will undoubtedly undermine the benefits sought after in the feasibility studies. Feasibility studies give an early indication of the soundness of the project, and their outcomes form the basis for negotiations with potential partners. All of this determines the viability of the project.

The value of project initiation work is also affected by the political decisions related to new regulations, spending cuts, etc. which lead to implications for the manpower development program, the level of safety and security measures, and the utilisation capacity that the research reactor can handle. Moreover, feasibility conditions are influenced by the measures the government takes in response to nuclear incidents or terrorism threats, which influence all the good preparation through detailed feasibility studies and reduce significantly the commercial viability of the facility.

3.3. Contextual conditions

The contextual conditions explain why the phenomenon is occurring in a certain fashion. "Contextual conditions are the specific sets of conditions (patterns of conditions) that intersect dimensionally at this time and place to create the set of circumstances or problems to which persons respond through actions/interactions" [14, p. 132].

The contextual conditions for the utilisation of a research reactor in the UAE has been determined to be influenced by the context of local and regional considerations and its properties: reliance on foreign support, viability of alternatives, and frequency of utilisation. Given that if all project initiation work was satisfactory with no governmental or political decisions hindering the outcomes of such studies, still there are conditions that are unique to the local practice that can negatively affect the utilisation of the research reactor. Although project initiation work could highlight the importance of local human resources development for the sustainability of operations, the country might opt for training its work force abroad and not consider the strategic importance of having control of the training program. Another issue is the frequency of use.

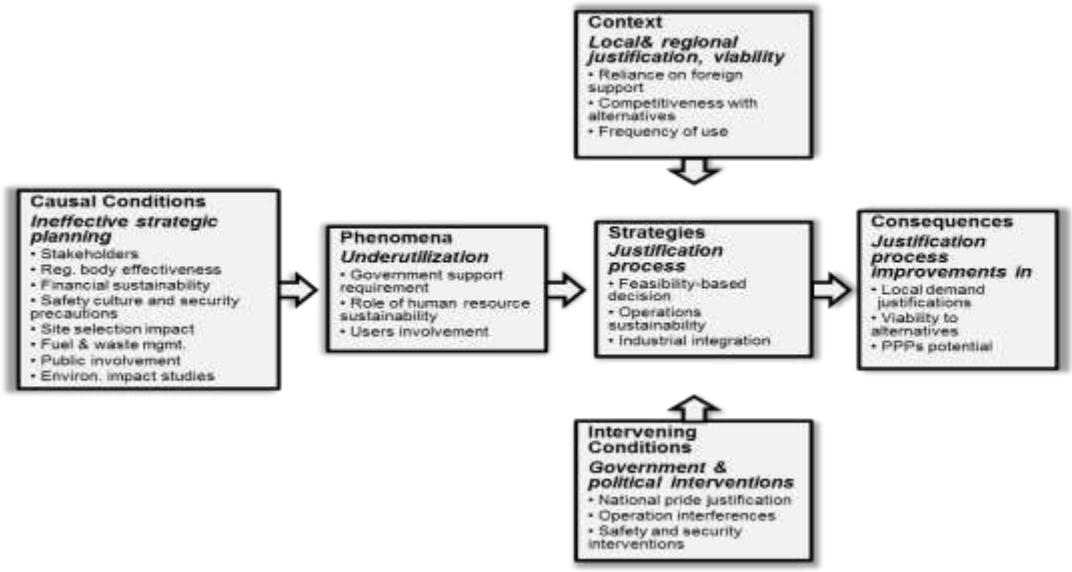

FIGURE 2: Axial coding paradigm

It is important to consider if local demand substantiates the operational cost of research reactors, and if the local research reactor can be a competitive alternative to the current providers/suppliers. All of these issues add a different dimension to the conditions that influence the level of utilisation and viability for the project [19,20].

4. Discussion

The conditions that create the situation pertaining to the success of RR must be discovered and their impact must be identified. This is necessary to link such conditions to the phenomena in an explanatory fashion- the axial coding paradigm- and to explain why and how the respondents reacted accordingly (*FIG. 2*).

The causal conditions for the underutilization of research reactors, as identified by the respondents, were mostly related to a group of factors that are mentioned in the 'strategic planning' terminology as identified in IAEA's [5] document, which is supposed to be completed at the early stages of the research reactor project. The causal conditions, as identified by the participants, included many concepts related to stakeholders, life-cycle financing and funding, nuclear safety and security, site selection, fuel and waste management, environmental and radiation protection, human resources development, and the regulatory body. These groups of concepts had the following properties: stakeholders' importance, regulatory body effectiveness, finance sustainability, business plan thoroughness, governmental support, safety and security precautions, safety culture, site selection impact, fuel and waste management, public involvement, environmental impact studies, and strategic plan for sustainable operations.

The main features of PPP will improve the sustainable operations of research reactors. "PPP arrangement provides assets and delivers services by allocating responsibilities and business risks among the various partners" [21, p. 54]. Such features add efficiency and effectiveness to the project, including the risk sharing, the life-cycle approach, the incentivised structure, the use of private funds, and the utilisation of the private sector’s experience and innovation. In particular, the direct involvement of stakeholders as partners ensures their long-term commitment to the project [22].

A strategic plan for sustainable operations of the research reactors is of paramount importance to their success and play a significant role in affecting their utilisation. The government must create a strategic plan for the objectives it is seeking from developing a nuclear program, where a research reactor is part of that plan and is well integrated within all other elements in the strategic plan. Once the identified objectives and the justified need for a research reactor is coupled with early stakeholder's involvement, it will improve the utilization and success rate of the research reactor [23].

Stakeholders' importance was highlighted by the participants as a major factor that influences research reactors. The respondents identified the operators, the users, and the regulatory bodies as the most important stakeholders in the field of research reactors. The operators are all those required in order for the facility to perform efficiently. The participants identified regulatory bodies among the most significant stakeholders in research reactor projects. A regulatory body, among others, ensures the requirements for the development of a research reactor, which takes into consideration the full life-cycle of the project, even years later the decommissioning, to deal with the storage of the spent fuel [24,25].

Financial sustainability, as identified by the participants, influences the attractiveness of the research reactor to the private sector and the roles of the industrial users in the operation of the reactor and plays not only a significant role in the success of the program, but also the security of the country. The respondents stressed on the issue that a research reactor could not simply shut down for any reason due to the long-term implications related to the nuclear industry. Another point that the respondents felt was very critical was the underestimation of the operation cost. Most research reactors are operating on a much higher cost than what was anticipated at the inception stage, which exposes the project to serious threats of shut down [5,26].

Safety culture and security precautions were identified by the participants as properties for the causal conditions influencing the success of research reactors. Participants highlighted the emphasis on safety and security issues as mandated by IAEA, as they are deemed to be the most important factors. The safety and security measures could impair operations and the proper utilisation of the research reactor. They stressed that there must be a balance between security measures and accessibility to the site by the users to enable a normal operation of the reactor and to cater to their daily industrial needs.

The respondents coupled the issue of safety and security properties with the measures taken for handling fuel and waste management, as the security is mostly related to the handling of fuel. Most respondents felt that this is a major issue for new comers, who do not have previous experience in handling the fuel.

The incidents and radiation accidents related to the nuclear power plants worldwide influence significantly the future of the nuclear industry. The respondents highlighted how the Fukushima incident changed the way the public looked at nuclear projects and how vulnerable people felt once the incident happened. The utilisation is undoubtedly influenced by these incidents.

Environmental impact studies serve many purposes and lead to improved chances for sustainable operations of research reactors. The respondents mentioned that the public wants assurances, for instance, that the cooling towers will not contaminate the water sources in the area, or release radiation into the air. Raj, Prasad and Bansal [27, p. 914] maintain that "the underlying objective that governs the management of all such waste is protection of man and environment. The most important factor is to actually make the public's role an integral part of the process and to involve them in the decision making process related to environmental protection. This will ensure that they will act more positively towards the sustainability of nuclear projects.

The intervening conditions that are found to affect the influence of the causal conditions on the success of RR were government and political interventions, including its properties: national pride justification, operation complications, and safety and security interventions. The interviews related to the weaknesses of research reactors revealed that most of the weaknesses had connections with the outcomes of the decisions made by the government or the political system. Moreover, the underutilisation also occurred because the designs of reactors were not a result of detailed consultations with the users, and therefore the research reactor could not satisfy their specific requirements.

Another political intervention that alters the causal conditions on the situation is related to operations interferences. The sustainability of research reactor operations depends significantly on the political systems, which are constantly changing during the long life cycle of research reactors. Every new government comes with a new agenda for the country, and this could affect the operations of research reactors in many areas. [28,29].

Safety and security interventions are another example of how the outcome of project initiation work could be impacted. A few respondents highlighted the extreme measures that their governments imposed on their research reactors in response to the accident at Fukushima.

Although research reactors are operating with no significant incidents, as the fuel used is very small in quantity, governments are including them in any measures taken for the safety and security of the much larger nuclear power plants. These interventions undoubtedly bear a severe impact on the operations of research reactors and minimize the outcomes identified in their feasibility study [30].

The local context for the UAE is unique. All of the participants interviewed highlighted the situation where the UAE has started its power generation program before starting first with a research reactor, which in their view was a brave move, as they could not recall any other country doing the same. This move, in their view, bore unforeseen circumstances. The training and experimenting for the much larger and expensive power plants are normally conducted in research reactors, and there are no viable alternatives to them for these scopes. Local human capacity is needed for the sustainability of operations of nuclear power plants; the respondents voiced their concern over the situation where foreign workers could leave at any time for many different reasons, such as political or economic changes in the region. Therefore, it is a strategic option to have a sustainable and reliable place for developing a local base of experts in nuclear disciplines [19].

The uses of research reactors are diverse, and each country in the region has a particular objective for using research reactors. Since local demand is satisfied currently by external options, regional countries could collaborate on a single multipurpose reactor, or multiple research reactors, with specific purposes within the region being available for the participating countries. This could be looked at as an interim development period until each country gains the skills required, realises a sustainable demand locally, and decides on having a local research reactor [20,31].

There are new technologies that must be assessed to establish the viability of initiating a research reactor project. Such technologies, although not suitable for all uses of research reactors, can provide an alternative for the users if they provide cost effective products. Such as the spallation neutron sources. "A spallation neutron sources comprise typically a source of high energy protons produced either by a cyclotron, a synchrotron or a linear accelerator" [5, p. 84]. According to IAEA, these technologies are yet to be tested and improved to cover the other uses offered by research reactors, and to justify their associated high cost. "When compared to a research reactor, the capital and operating costs of a spallation neutron source are significantly higher" [5, p. 85]. IAEA [5, p. 84] cited the weaknesses of spallation sources, for instance, "they are normally not designed for continuous operation and have not been used for the routine production of radioisotopes". However, this issue should not be overlooked by the decision makers while assessing the alternatives and the viability of the new research reactor, due to the technological evolutions that may improve the viability of accelerators to research reactors.

Another contextual property related to the local context is the frequency for using the research reactor by the local authority. If there will be reliance on international research reactors and the plan is only for occasional training and staggered research uses, then this will never justify the high cost associated with the operations of a research reactor. As mentioned earlier, to run research reactors there are many factors to take care of, such as the recruitment of skilled operators, the safety and security measures, spent fuel management, and others. So, if the uses of the plant will not justify the high cost associated with such uses, there will be no viability for having a research reactor project.

FIG. 3 represents the final framework for developing a research reactor project through utilising the PPP mechanism, which completes the aim of this research. It is consisting of the three objectives identified to deliver this aim. The framework consists of the generic PPP

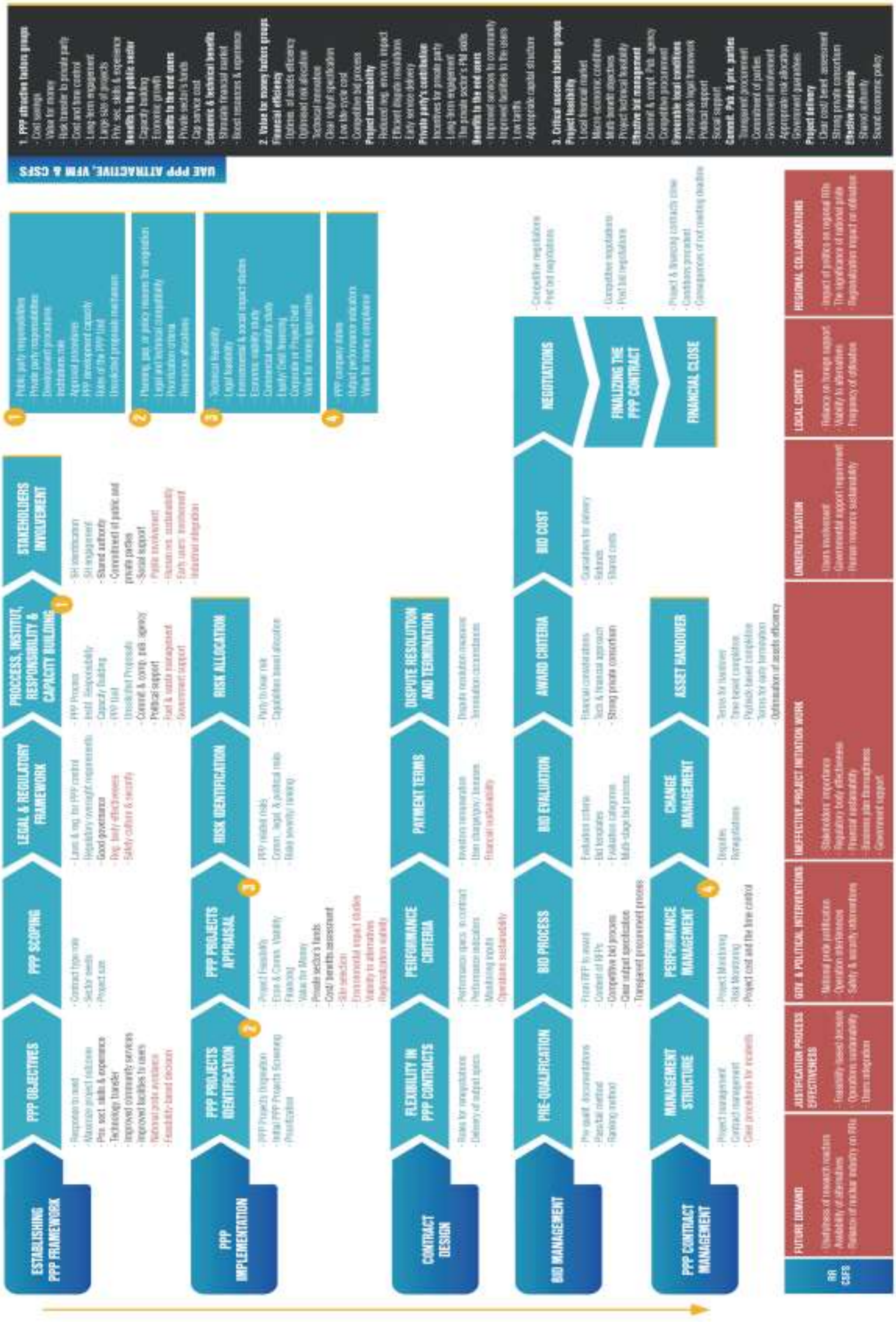

FIG. 3: Framework for Implementing PPPs in RR Project in the UAE

framework, plus the favourable factors, value for money factors, and the critical success factors for UAE PPP implementation, plus the critical success factors for a research reactor project in the UAE.

5. Conclusion

Through the constant refinement of the relationships in this study, the following propositions (relationships) were generated:

Intervening proposition

Government and political interventions alter the value of the justification process and influence directly the utilisation and subsequently, the potential for users' integration in research reactors. Government and political interventions include national pride justifications, operations interferences, and safety and security measures.

Contextual proposition

The proper utilisation of research reactors depends on the influence of local and regional justifications and on the outcomes of the project initiation work. Local and regional justifications include local demand justifications, viability of other alternatives, and partnership potential.

Strategies proposition

The strategies in response to the justification process that influence the utilisation of research reactors are expected to address the issues of feasibility-based decisions, sustainability of operations, and industrial integration.

Consequences proposition

The consequences of the strategies taken to improve the justification process lead to improvements to the utilisation of research reactors, and they include demand justification improvement, viability of available alternatives improvement, user integration, and the PPP's potential improvement.

The findings of this research produced a best practice framework for developing research reactor projects in newcomer countries through the PPP mechanism, where the UAE was taken as a case study.

The PPP framework for research reactors is a new area, and there are no empirical studies, that this researcher could find in the open domain or as confirmed from the interviews with the nuclear experts, that studied PPP implementation for RRs before. Therefore, this study is significant and opens a new area to improve the partnership practice in research reactors.

The contributions of this research to the body of knowledge is that this study considered the underutilisation phenomenon of research reactors and identified the critical conditions influencing such phenomenon to improve the operations of research reactors. Such conditions could be scrutinised further as identified constructs that are rigorously substantiated by theory.

Regarding the research reactor experts, although the minimum number of interviews was achieved, a larger sample could have highlighted more areas for consideration, especially in the areas of partnerships with the private sector, as most experts interviewed come from a solid technical background.

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