Contracting Formulas for Large Engineering Projects. The Case of Desalination Plants

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Abstract: Population growth has increased over the past two centuries. In the driest countries, water supply alternatives are scarce, with desalination being an alternative to ensure water supply to the population. Desalination plants have increased in size and efficiency, and require large investments, large infrastructures, and complex technology, besides they also need sophisticated contractual formulas to successfully build them. Various contract models are tools that should be used by taking into consideration the characteristics of the project, the parties involved, and who is responsible for each of the risks involved. To help choose the most suitable type of contract for a particular project, so-called decision support systems have been developed over the past thirty years. In this paper, a new decision support system is presented and applied to a case study of two desalination plants built under the design and build and turnkey modes of contract. The objective was to determine the most suitable contract model for these types of projects which had very ambitious objectives and decisive social, economic, and environmental implications.

Keywords: desalination plant; contracts; projects; sustainability

1. Introduction

The completion of a project is basically based on two operations: the conception of the work and its execution. How and when these activities are carried out, the role of each party involved in the project, and the conditions during the development of the project are the basic issues that the contract must include. The different possibilities to answer these questions are the origin of the different formulas to develop a project that gives rise to the different contractual models. Contractual models are tools that should be used after considering the characteristics of the project, the parties involved, and the responsibilities assumed by each of them regarding project risks. The contract model chosen is a key factor in the successful achievement of the objectives of the project.

Large infrastructure projects require large investments, they are highly complex technological structures to build, and require sophisticated contractual formulas to achieve them successfully. This is especially true in water desalination projects, which we will discuss in this paper for their complexity and how they help to understand the importance of the type of contract chosen for their development.

Human population growth has accelerated over the past two centuries and is forecasted to grow from the current 7.7 billion to about 10 billion by 2050. One of the great challenges that will limit global population growth is the supply of drinking water in the coming years.

Water supply alternatives are not very plentiful, and in some parts of the world water, scarcity is manifesting. Water desalination is a necessary alternative to ensure water supply to the population and will become even more important in the future.
Sanz [1] explains the growing supply of desalinated water in the world, estimating that by 2025 it will exceed 150 million cubic meters per day and the population supplied will increase from 5% today, to 25%.

The main producers of desalinated water are Saudi Arabia, with 17% of world production, the United Arab Emirates with 13.4%, and the United States with 13%. The Spanish Association for Desalination and Reuse (AEDyR) in its latest report [2] states that Spain is the fourth producer of desalinated water in the world, with a total of 900 desalination plants and a daily water production of approximately 5 Hm$^3$/day for irrigation and industrial use.

According to data published by the International Association for Desalination (IDA) and the Global Water Intelligence (GWI) in its 30th inventory [3], installed global desalination water production capacity was 99.7 Hm$^3$/day, with a total of 19,744 desalination plants worldwide.

The significant increase in desalination plant size due to technological advances and the economies of scale makes the development of these projects increasingly complex. Now, more than ever, the bidding process used, the financing, the chosen contract modality, the operation, and maintenance are key factors to successfully achieve the objectives set in the development of a desalination plant, which are: the supply of quality drinking water, in an environmentally friendly manner and in an economically competitive way.

The purpose of this paper is to analyze, through a case study, the influence of the contractual formula used in the construction of desalination plants for drinking water supply and to determine which is the most appropriate.

In this case study, the differential factors of two important desalination plants are highlighted in a comparative way: the Oropesa-Cabanes desalination plant (OCDP) built in Spain in the “Design and Built (D&B)” modality and the Southern Seawater Desalination Plant (SSDP) developed in Australia through a “Turnkey Contract (TC)”.

The scientific contribution of this paper is to identify the determining factors that allow us to analyze the feasibility of developing a particular project. The goal is to provide a decision support tool or system (DSS) to help developers and contractors choose the most appropriate type of contract to develop a project, by considering the circumstances that will condition its development. According to the authors’ experience in the development of these types of projects, the determining factors identified to analyze each project were: customer, contractor, contract, budget, financing, risks, and technological developments.

This methodology contrasts with the usual DSS methods for the evaluation of projects and is one of the important contributions of this present research.

Accumulated experience and the information collected in databases have made it possible for such systems to evolve and build computer models for quantitative assessments to be made and justify decisions taken by the public sector. In comparison, the procedure discussed in this paper can be used for any type of project in a general and objective manner.

2. Background and Theoretical Framework

In the procurement of major infrastructure projects, Olalde [4] states that the most appropriate type of contract will depend on:

- Immediate availability of all information.
- Project targets (timeframe–price–quality).
- Technical capacity and the means available at the moment.
- Economic and financial conditions of the project.
- Market situation at the moment and its foreseeable evolution.
- Objectives of the contract.

To enter into a TC contract, it is necessary to analyze the origin and development of this contractual modality. With the emergence of the TC, Butlow [5] refers to the guiding idea of the contract born in
the field of engineering contracts in which more than design, direction, and construction of the project were required: experience, capacity, and training to be able to run a complex undertaking properly, such as a water treatment plant, communication systems, or an urban infrastructure.

For Ohrn and Rogers [6], the purpose of the D&B method is to return the form of construction prior to the appearance of the now traditional “Design-Bid-Build” method (DBB). The D&B method offers the customer a contract with a single contractor, and the design is made by the same contractor. This method has the advantage that construction can actually begin before the completion of the project design, thus saving time. In addition, because the design is done by the contractor, integrated services are also provided. This definition of D&B adopted in the United States is similar to TC, which emerges as an evolution of the last one, as will be seen below.

Hernandez [7] states that the only aspect in which there is consensus in the definition and characterization of TC is in the contractor’s responsibility for the completion of the whole project. The contractor agrees with the customer, in exchange for a price, usually raised (on a fixed price basis), to conceive, build, and put into operation a certain work that the contractor had previously designed.

Hernández also states that in the “D&B” contract, the common law system follows, the contractor undertakes to conceive and execute the project according to the needs and demands of the client. So, the benefits of this contract are limited to the construction operation itself. What is not included within D&B contracts (in contrast to the case of TC) are obligations such as the commissioning of the installation or the training of personnel. Hernández states that a D&B contract can never be equated to a TC, but it nevertheless encompasses the obligations arising from the first. This makes sense when considering that, internationally, the D&B contract has served as the basis for the configuration of international TC contracts.

Under international contracts, developers opt for TC procurement following award procedures determined by the call for tendering, widespread use of a prequalification procedure for companies, and a clear tendency for a restricted and negotiated procedure.

In Spain, the differences between D&B and TC contracts are the responsibility assumed by the contractor and the moment when the engineering and construction takes place. In the first case, according to the Public Sector Contracts Act [8], the design of the project must be completed and have been approved by the public sector entity before construction begins. In the second contract model, basic engineering and initial detail engineering work is carried out, and with this documentation, the construction phase begins. From this moment on, the engineering is carried out in parallel with the execution of the works, in such a way that the final project document is available, once they have been completed. This is the so-called “as built” project.

Jordan [9] explains the differences between EPC (engineering, procurement, and construction) and D&B, pre-clarifying the common characteristics in both cases: the promoter has a single interlocutor, the contractor, who is responsible for the design and assumes more risks than in a traditional D&B contract. But there are differences such as:

- An EPC project usually results in a turnkey installation. Upon completion, the EPC contractor delivers a ready-to-run installation. A D&B contract is similar to DBB contracts, with an active role of the owner upon receipt of the installation. There is also no EPC equivalent of the D&B processes “design assistance” or “accelerated process”. This reflects the customer’s minimal involvement in the EPC design process.
- EPC contractors often have performance requirements (output levels, uptime levels, maximum maintenance costs, etc.), while most D&B contracts provide design details in customer communications during execution.

In terms of risk, D&B contracts tend to take a traditional DBB approach of unknown elements, to share that risk between the customer and the contractor. In contrast, it is not uncommon for EPC contracts to assign these risks to the contractor.

Finally, it is advisable to identify the differences between TC and EPC, usually considered similar contracts. So, the International Federation of Consulting Engineers (FIDIC) published in 2017 the
“Silver Book” (contracting conditions for EPC/TC) [10], which includes contract-type models without making a distinction amongst them.

Rahman [11] summarizes the differences between TC and EPC contracts. In the EPC, the customer provides basic engineering to the contractor to develop a detailed design based on the basic design provided by the customer. For TC, the customer will only provide the technical specifications of the project and it is the contractor’s responsibility to prepare the basic and detailed design of the project, carry out the construction and commissioning of the infrastructure until the customer inaugurates the finished project. In EPC contracts, however, it may be the responsibility of a third party to make the delivery and commissioning of the installation.

Ding Jiyong et al. [12] state that the type of contract and strategy followed by the development of a project are two critical factors for projects in the construction industry.

It is interesting to describe a type of contract that has become relevant in recent years, called “Open Book Estimation (OBE)”. This consists of an agreement between client and contractor to carry out work in which the costs are paid to the contractor and increased by a previously agreed margin. The customer and contractor will agree on the way to pay for the works, with the ability to agree to convert to a TC. This approach will reduce project risks, contingencies, and deviations in the construction phase and result in a better end result with a more transparent and fair treatment of the actual costs of the project. The School of Industrial Organization [13] set out the characteristics of these contracts, showing that in an OBE contract, the risks are shared, enabling external funding with EPC.

It should be noted that time and budget deviations are not unique to a procurement method. There are many circumstances that influence the final outcome of a project. It is necessary for the client to do a preliminary study that will lead the client to determine the type of contract appropriate for the project.

The most significant characteristics of the contract types discussed in the present paper are:

- The role of the client, who is more active in the D&B than in the TC, both during the development of the work and in the reception and commissioning. The customer’s participation is minimal in the process of designing the turnkey contract and usually receives the finished project after commissioning.
- In most D&B projects, the contractor provides design details during execution that must be approved by the client. The contractor of a TC often has performance and result requirements.
- The risk to indefinite contractual elements in D&B contracts is shared between the client and the contractor, thus adopting a traditional approach to DBB. In contrast, it is not uncommon for TC contracts to assign these risks to the contractor.
- At the international level, the D&B contract has served as the basis for the configuration of the international construction TCs. So, while a D&B contract cannot be equated to a TC, it always includes the obligations found in D&B contracts.
- The TC has emerged from the business practice to respond to the needs of customers and is linked to the transaction of the project.
- Turnkey procurement gives confidence to financial institutions and international and multilateral agencies in the international construction market.
- In a TC, the engineering is carried out in parallel with the execution of the works, while, in Spain, in a D&B, the design of the project must be completed and approved by the public sector before construction begins, thus complying with the Public Sector Contracts Act.

Table 1 is a summary of the D&B principal contract characteristics (according to Spanish legislation) versus the TC.
Table 1. Design and Build (D&B) contract characteristics vs. Turnkey contract (TC).

|                      | D&B                                                                 | TC                                                                 |
|----------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|
|                      | A single contractor develops the design and construction             |                                                                       |
| Promoter (owner)     | has to approve the engineering (design) before construction begins.  | It allows the parallel development of design (engineering) and construction. |
| Approval of engineering limits contractor responsibility. |                                                                       | Overall contractor responsibility.                                  |
| Approval of engineering does not prevent modified work and claims during construction phase. |                                                                       | There is usually no modified work during the construction phase and the contractor’s claims are very limited or do not exist. |
| Open bidding process. |                                                                       | Restricted bidding process.                                          |
| All aspects of the contract are provided by Public Sector Contract Law (public law). |                                                                       | Most developed countries allow the use of the TC for the administration. This option is not possible in the European Union and Spain. |
|                      |                                                                       | It reduces the number of bidders considerably, focusing on companies with the capacity to develop the project. |
|                      |                                                                       | It requires the client to have teams (own or contracted) with experience and knowledge to supervise the execution of these types of contracts. |

In the field of desalination, the TC stands out as the most efficient tool for the development of projects, offering the following advantages:

- Concentrates on a single contractor design and work.
- It offers faster development in parallel engineering and construction.
- Reduces communication needs between owner–contractor.
- Change or changed orders that generate time and budget variances are removed or reduced.
- The contractor exclusively assumes the risk of the technological developments.
- The contractor is responsible for compliance with the quality requirements established by contract.

Finally, it is required by law that any project has to include an environment impact study and the measures taken to correct them in the construction phase, including a program to monitor their compliance during the life of the project. This aspect is especially controversial in desalination plants. Saracco [14] warns of the risk of brine contamination and the need for corrective action. In the major desalination projects, this issue is dealt with the importance it deserves. Martínez Vallina [15] and the Water Corporation [16] are examples of this environment requirement.

The traditional method of design–tender–construction (DBB) was the most used for the development of projects in the twentieth century. However, customers noticed shortcomings in this system. Gransberg, Koch, and Molenaar [17] talk about the lack of quality in engineering (design) and in the selection of the construction company, basing the award primarily on the price. The objectives of quality, deadline, and budget were rarely achieved. As a consequence of the above, the “Design and Build” model, the construction management at risk, and other systems appeared.

The opening of the contract types favored professionals in the sector who proposed methodologies that would help the owners find the most appropriate contract method for each specific project. These decision support methods or systems are known in the international construction market as “Decision Support Systems” (DSS).

We introduce, in the present paper, a new DSS to choose the most appropriate type of contract for the development of a project, such as the “Project and Work Selector” by Molenaar and Songer [18],
and those by El-Wardani [19] or Thomsen [20], the guide to evaluate types of U.S. Federal Highway Administration transportation contracts [21], the Transportation Research Program Guide, Transit Cooperative Research Program (TCRP) Report 131 [22], and other predictive models.

Existing support systems for determining the most appropriate type of contract are useful, but not perfect. They are limited in the range of projects they can be applied to and in the evaluation criteria, given they exclude key factors when deciding the model of contract more suitable for certain circumstances. In addition, they do not address the concerns of public bodies nor do they specify the requirements of contractors, or the financial conditions necessary for their feasibility, risks, or technological developments.

To define a DSS applicable to any type of project, we refer to the definition given by David I. Cleland and Harold Kezner [23]: “a combination of human and non-human resources gathered in a temporary organization to achieve a specific purpose”. This definition emphasizes the fundamental characteristics of any project: combination of resources, temporary organization, objectives, and deadlines that enables us to identify the determining factors common to all contracting modalities:

1. **Client.** Client quality was assessed to define precisely the scope and objectives of the project; contractual manageability; whether they have adequate personnel or a team of consultants; whether they can properly coordinate contractors; and their expertise in developing similar projects.
2. **Contractor.** Contractors are assessed for their financial solvency; technical experience from similar works and their availability to be part of temporary joint ventures and consortia; check their suitability to respond appropriately to the needs of the project.
3. **Contract.** It is necessary to qualify whether a type of contract is appropriate for the proposed project and the particular circumstances of all the parties affected by it; identify the responsibility assumed by each of the parties and the distribution of risks amongst them.
4. **Budget.** The form of payment; the fulfillment of the established milestones; the possible claims; the treatment of costs not covered by the budget; the guarantees and the evaluation of the work carried out in the event of a halt or termination of the contract.
5. **Financing.** Financial availability is considered prior to the signing of the contract; information on public funds and the necessary requirements to apply for them; the availability of independent companies to audit the progress of the project; and how it affects the total or partial external financing in the work certification.
6. **Risks.** Client risk, contract risk, contractor risk, financial risk, country risk, and governance risk are also assessed.
7. **Technological Developments.** Evaluation of the offers considering the parties that improve the project during the construction phase and during the life of the project; the competition improvement aspects by assessing the life cycle of the infrastructure; and efficiency of the processes, consumption, maintenance, and quality.

A determining factor regarding the corrective actions of environmental impacts is not included, because they are mandatory by law in countries with the capacity to build large infrastructure.

For a given project, the proposed methodology allows qualitative and quantitative evaluation of each determining factor depending on the contracting modality selected, indicating which type of contract is most suitable to develop the project under study successfully.

### 3. Case Study

Large infrastructure projects require a complex contractual structure that meets the needs of the project. This has led to the appearance and application of different types of contracts depending on the characteristics of the project, the actors involved, and risk-sharing among them. Choosing the right contract type is a key factor for the success of a project.
Desalination plants are a clear example of a large and complex project, due to the growing need for potable water to meet human needs and protect the environment.

For the case study presented in the present paper, we selected two large desalination plants, Oropesa-Cabanes (OCDP) built in Spain with a D&B model contract and Southern Seawater Desalination Plant (SSDP) developed in Australia through a TC. Both plants were promoted and contracted by public sector companies under the control of the administration.

These two plants were chosen because they represent two large and complex projects developed in two completely different contexts: Australia and Spain. Although in both cases the owner was a public entity, the legal and contractual aspects mean that the completion of both projects had important differences. In addition, the authors had the opportunity to participate in both these two projects.

In Spain, the Public Sector Contracts Law [13] does not allow turnkey projects, so the state company chose a D&B type contract to avoid budgetary deviations and any claims by the contractor in charge of design and completing the project. In Australia, following Western Australian State legislation, the contracting public company used the turnkey contract model, with the contractor taking full responsibility for the development of the project. These two projects make a good comparative study including the form of contract and their development and results. A brief description of each project is given below, and an analysis of the projects is given in the next section.

3.1. Oropesa-Cabanes Desalination Plant (OCDP)

The D&B project was carried out for the Sociedad Estatal Aguas de las Cuencas Mediterráneas, S.A. (ACUAMED) in Spain (2009). The aim of the project was to provide safe and quality water to 150,000 inhabitants (first phase) of the municipalities of Alicante, Oropesa del Mar, Cabanes and Benicassim (Valencian Region). Production capacity was 17.5 Hm$^3$/year, expandable to 43 Hm$^3$/year.

The main features considered when designing the plant were:

- Modularity to adapt to seasonal demand, because Alicante is a province with a large tourist population during the summer.
- Contribution to the improvement of water supply and quality.
- Contribution to tourism promotion and the development of the area.
- Careful environmental and architectural integration.

The distinguishing feature is the seasonality of demand, which led to the projecting of different reverse osmosis frames with a unit production capacity of 8125 m$^3$/day, adjusting production units depending on seasonality demand. The project was conceived so that production could increase in different future scenarios. In the first phase, the plant would have a total production capacity of 48,750 m$^3$/day (6 racks), but the rest of the civil works was designed for 65,000 m$^3$/day (8 racks). However, both the size of the land, the shot work, and the brine pouring work were prepared for a production of 130,000 m$^3$/day (16 racks), which would represent its maximum development.

The tendering process, according to the Public Sector Contracts Act (Consolidated Text of the Law on Contracts with Public Administrations, 2000 [24]), was an open D&B procedure without negotiations, which required following the tender specifications.

3.2. Southern Seawater Desalination Plant (SSDP)

This plant is located on the coast on Taranto Road, between Binningup and Myalup, 130 km south of Perth in Western Australia. It is a turnkey project for the Water Corporation of Western Australia, owned by the Government of Western Australia, whose Ministry of Water is responsible and sole shareholder. The Water Corporation is the leading provider of drinking water and wastewater treatment services to more than two million people over more than 2.6 million square kilometers in Western Australia. The project was built in two phases of 50 Hm$^3$/year each. The first was inaugurated in September 2011 and the second reached 100% of its production in January 2014. The contract included 25 years of operation and maintenance.
The basis of the design was the contractual requirement to operate and maintain the plant for a period of 25 years. Issues regarding durability, materials, configuration, or control system, among others, were considered within the context of a 25-year life analysis. For the design, the following factors were of particular relevance:

- Security in construction and operation.
- Use tanks between different process areas. These areas are insulated so that no transients are transmitted from one to the other, while commissioning is done more easily.
- Design a safe plant and easy to start and operate.
- Employ a level of redundancy for flexibility and operational assurance.
- Achieve the lowest specific energy consumption possible.
- Design a plant capable of updating with the new membrane developments that the future will bring with the minimum cost, both in reverse osmosis and ultrafiltration.
- The distinctive features of the plant include:
  - High quality civil works, equipment and architectural design.
  - One of the world’s largest pretreatments with ultrafiltration membranes (UF) (720,000 m$^3$/day filtration capacity).
  - High availability factor (95%, 345 days/year).
  - High quality of water produced; partial double step for reducing the concentration of bromide below the limits of Australian drinking water quality standards.
  - Membranes in hybrid configuration (different types of membrane inside the pressure tubes) and with split water extraction on both sides of the tube, enabling reduced energy consumption and the size of the second step.
  - Very low energy consumption design: 3.72 Kwh/m$^3$ in total including the two steps of osmosis and pumping water product representing 0.58 Kwh/m$^3$.
  - Environment friendly.

The complexity of the bidding process followed by the Water Corporation to award the first phase is noteworthy. The process consisted of an open announcement to companies around the world to provide technical references and sufficient economic solvency to develop the contract by tender. The Water Corporation reported an “initial short list” of five companies, which were then visited by members of the corporation at the respective headquarters and relevant projects of each company. Finally, they decided on a “final short list” between two consortia.

During the next step of the process, both groups developed a tender project in Perth for a period of six months. Each company organized work teams who were assigned for this purpose. The work teams of engineers were based on-site as resident engineers. For this work, both consortia charged a pre-determined amount of money to cover the costs. At the end of the deadline, each group proposed a closed financial offer and a technical proposal that would be contractually binding if it was selected. The second phase was carried out by a negotiated procedure with the successful tenderer of the first phase, once the milestones set in the first phase were completed successfully.

4. Analysis of the Case of Study

As mentioned already, the novelty of the present paper is the methodology developed and used in the analysis of the projects, with which we can compare and determine the best type of contract. The support method used can be applied to any type of tender project and analyze both the qualitatively and quantitatively key factors (determinants). It should be taken into consideration that the two projects are in operation at the time of writing, but the proposed methodology is applied to compare the validity of their forecasts with the known ex post results.

As we have mentioned before, first of all, we applied the methodology to analyze the indicated determinants in a qualitative way:
1. **Client.** Acuamed, the owner of the OCDP, had experience in the development of similar projects, but with breaches of term and budget in each of them. In the project under study, they showed a lack of management capacity. Water Corporation, the SSDP client, had experience and procedures to develop a large infrastructure contract.

2. **Contractor.** The winning consortium of OCDP had problems because one of its companies was affected by problems arising from the 2008 economic crisis. The winning consortium of SSDP, with experience in similar projects, had to function properly in the project.

3. **Contract.** The OCDP was developed with a D&B contract in accordance with the Spanish Public Sector Contract Law [23], since it does not allow turnkey contracting. The SSDP was developed as a TC project.

4. **Budget.** The OCDP budget, in accordance with Spanish Law, was set by bidders in their offer, and must always be lower than that provided by the administration. In the SSDP, the competition preparation phase between the finalist consortiums and the possible negotiation of contingencies and risks, favored a tight budget without deviations.

5. **Financing.** In the Oropesa Cabanes desalination plant, unforeseen and deviations in terms of time negatively influenced the financing of the project. In SSDP, the planned financing was met in parallel with the fulfillment of deadlines and budget.

6. **Risks.** In the OCDP, certain risks were underestimated as the client is a public company dependent on central government. The risk analysis carried out for the SSDP project, which is located in a different country, was much more thorough and complete.

7. **Technological Developments.** In both contracts, the companies offered adequate technological developments consistent with the uniqueness of these infrastructures.

Table 2 gives an easy comparison between the two selected projects. Each of the key factors were assigned a score of 1 to 5, which indicates the degree of compliance of each factor determinant in each of the analyzed projects. A score of 1 being the lowest degree of compliance and 5 being the optimal degree of response (Table 3). The maximum number of points a project can get is 35.

For each of the contract model analyzed, the method was applied by indicating the degree of compliance for each determining factor, so that the higher the score, the more appropriate was the type of contract chosen to develop the analyzed project. A low score assumes that the contract model was not suitable for developing such a project.

This section then justifies the assessments carried out for each determinant, the number of which will indicate the suitability or otherwise of the contract method selected to develop each of the two desalination projects chosen for the case study.

Finally, the activities that occurred in each project were collected to compare the actual results obtained with those obtained by applying the determining factor method.
Table 2. Comparison of the distinctive determinants of the two case study projects.

| (1) Client | Oropesa-Cabanes Desalination Plant (OCDP), Spain | Southern Seawater Desalination Plant (SSDP), Australia |
|------------|-------------------------------------------------|-----------------------------------------------------|
| Client     | Public Company of the Government of Spain. Experience in construction of more than 20 desalination plants, but with breaches of term and budget in each of them. | Western Australia Government. Responsible for supplying drinking water and treatment for more than 2 M. inhabitants. Successful experience in construction of 1 desalination plant. |

| (2) Contractor | Consortium made up of 3 companies, 1 with experience in the construction of desalination plants | Consortium formed by 4 companies, 2 Spanish companies with experience in turnkey construction and desalination plants + Australian engineering company and construction company. |

| (3) Contract | Project and Work according to Spanish legislation on Public Sector Contracts. Requires Project approval before starting work. No negotiation. Accession to the Contest Base Fold. Contractual term: 3 months (Project) + 18 months (Work). Delays, stops, deferrals: delivery in 2015 (award in 2007). | Turnkey responsibility of the Contractor. Negotiation in the bidding phase between the Client and the two finalist consortia. Includes proposals for technological developments. Term 1st Phase: Contractual, 28 months. Completed in 26 months. Term 2nd Phase: Contractual, 22 months. Completed in 24 months. Deadline compliance |

| (4) Budget | Award: 52 M€ Final (included modified): 55.5 M€. Deviation of 6.73%. With partial funding of European funds. | 1st Phase: 475 M€. 2nd Phase: 350 M€. Compliance within budgets. No deviation. Funded by the Government of Western Australia. |

| (5) Financing | Work certification with milestones. No billing during periods of waiting for project approval and obtaining permits | Initial payment ("Dawn payment") + payment milestones. Monthly certifications of work carried out. Monthly margin invoicing in the award percentage. |

| (6) Risks | In addition to those inherent in a Project and Work contract, the requirement of prior approval of the Project before the start of the Work entails added uncertainty, which may result in losses for the Contractor claims to the Client. | The ones of an international turnkey contract, to highlight country risk (legal security, currency, industrial fabric); contract management risk (planning and control, cash flow and costs). |
Table 2. Cont.

| Oropesa-Cabanes Desalination Plant (OCDP), Spain | Southern Seawater Desalination Plant (SSDP), Australia |
|-------------------------------------------------|------------------------------------------------------|
| • Energy consumption optimization: The rejection pressure is transformed by energy recuperators, which with the help of Booster pumps, allow to reach 71 bars of working pressure. | • Split-hybrid configuration of the first step that reduces energy consumption and second step sizing. Membranes with high salt rejection located on the front of the pressure tubes produce water that is extracted from the front and sent directly to water purification. The rest is sent to an intermediate depot that supplies the second step. |
| • Environmental criteria: Storage of brine for filter washing, evacuation of brine to sea by gravity, neutralization of filter washing discharge, and chemical cleaning with neutralization equipment. | • Flexible system configuration. There is no fixed connection between first step and second-step racks. There is no direct coupling between permeate manifold and second step feed system. |
| (7) Technological Developments | • Nominal conversion rates of 45% and 90% in first and second steps respectively. They can be adjusted to the operating conditions caused by the split-hybrid design and the production needs of the plant in case of rack maintenance stops. |
Table 3. Quantitative valuation. Own assessment.

| Projects Determinants          | OCDP | SSDP |
|-------------------------------|------|------|
| (1) Client                    | 2    | 5    |
| (2) Contractor                | 3    | 5    |
| (3) Contract                  | 2    | 5    |
| (4) Budget                    | 2    | 5    |
| (5) Financing                 | 2    | 5    |
| (6) Risks                     | 2    | 4    |
| (7) Technological Developments| 3    | 5    |
| TOTAL                         | 16   | 34   |

The assignment of qualifications is for the qualitative assessment of the determining factors, justified by the degree of compliance with the criteria defined for each of the types of contracts chosen:

1. **Client**: Scored a 2 in the OCDP project for the lack of capacity to manage the project; lack of coordination with other public administrations affected and the non-compliance with deadlines on their part. While in the SSDP, all criteria were met, so the maximum score was assigned.

2. **Contractor**: Scored a 3 for OCDP because one of the partners had serious economic problems that led to changes that affected the awarding consortium; the local partner failed to meet the objectives based on their specifications and did not take steps to avoid the prolonged and successive construction stops. In the SSDP, all requirements were met, so it was evaluated with a 5.

3. **Contract**: A 2 was assigned to the OCDP project because the condition of completion and prior approval of the project did not work due to non-compliance with the deadlines set out in the contract by the customer, the responsibilities set, and the complaint mechanisms were breached. Quite the opposite of SSDP, rated 5.

4. **Budget**: The 2 score indicates the clear budgetary inadequacy for the project and work of the OCDP, under the conditions it was actually carried out. While 5 indicates the success of the SSDP.

5. **Financing**: The OCDP project was allocated a 2 for the negative condition in the unforeseen stop periods of construction and its impact on demobilizations and mobilizations not considered during the supply period. The 5 awarded to the SSDP indicates strict compliance with the commitments.

6. **Risks**: The 2 score indicates a clear deficiency in assessing the risks of the OCDP, undoubtedly due to false assumptions of risks by working within the country itself with institutions dependent on central government. The 4 assigned to SSDP notes that despite having carried out a thorough analysis up to the last phase of bidding, during the development of the project unexpected problems arose with local subcontractors that had to be managed at a late stage.

7. **Technological Developments**: For the OCDP, the 3 score assesses the perfect response of the solution developed to correct the environmental impact of a desalination plant; it also reflects the demand characterized by strong season cycle and energy efficiency in the desalination process. The highest score given to the SSDP reflects the above number of extraordinarily demanding requirements in terms of environmental impact correction, energy consumption, and other characteristic ratios that led to the award of the best desalinating plant in 2012.

In short, the OCDP project received 16 points out of a 35-maximum score, while the SSDP, 34 out of 35 points. The evaluation indicates that the D&B contract model was not suitable to develop the OCDP with guarantees. The analysis, however, confirms the suitability of the turnkey model in the development of the SSD project.

It must be remembered that in the Spanish case, the public sector contract legislation does not provide for turnkey contracts, which has been shown to be suitable for the Australian project. This case
study shows the advantages of a turnkey model to develop highly complex projects, such as a modern desalination plant. The following is a summary of the success and failure causes of the two projects in the case study.

The D&B contract for the OCDP project in Spain was chosen to avoid modifications to the project due to unforeseen factors or errors in the project. The goal was not achieved, due to:

- Lack of adequate legislation.
- Following the customs and habits of traditional procurement.
- The absence of the concept of global responsibility placed on the contractor, who took advantage of the management of work exercised by the administration and the failure of deadlines to make important economical claims.
- The risks assumed by the contractor are limited due to the status of the limited liability company.

However, the final result did not favor the contractor, since the time consumed by the company to approve the engineering specifications before starting construction far exceeded that provided for in the contract. Other stops were caused by lack of permits or authorization from other local and regional administrations, resulting in cost overruns that were claimed and only partially allowed. The contract was developed in the midst of an economic crisis and was affected by the consequences of tension amongst the various public administrations involved, i.e. state and municipalities. Both signed an agreement that guaranteed water supply required that the municipalities covered depreciation and operating costs. Budget cuts and the non-completion of major urban development projects blocked agreements signed over the years. The direct consequence of these circumstances was the significant deviation of time and budget, and the parties involved in the project were, thus, harmed.

The Southern Seawater Desalination Plant Turnkey contract was established with a tender to obtain the best desalination plant in the world. To achieve this, the Water Corporation took special care in:

- The contractor selection process.
- Contractual documents with clear identification of responsibilities in accordance with a turnkey contract.
- The high risks demanded of the consortium, as a result of global responsibility and the high budget.

The end result of the whole process was the fulfillment of objectives, deadlines, budgets, and technical quality. In addition, the economic performance was favorable to all the parties involved.

5. Conclusions

Based on the determining factors of any infrastructure project, the proposed methodology can be employed to adequately evaluate different contract models. The two chosen desalination projects as case study are of comparable size and complexity. The main difference between them is the contractual formula selected for each project.

The two desalination plants were chosen for the present case study because in recent years these type of plants have become larger in size and more efficient, requiring large investments, with more complex construction requirements and technology. More importantly, these projects require sophisticated contracts to make them successful.

The type of contract chosen to develop the OCDP was not adequate, confirming that the application of the determining factors method (16/35 points) coincides with the bad experience during the completion of the project, which demonstrates that the D&B contract was not suitable for this type of facility.

The contract chosen to develop the SSDP obtains 34/35 points when applying the determining factors, indicating the suitability of TC and the good results obtained. Within the most widely used contractual modalities in the international infrastructure market, the TC is the one that offers the
best response for the development of large and complex projects, where the weight of technological developments is important when choosing a successful bidder.

The proper development of a desalination plant by means of a TC requires consideration of the following aspects:

- **Risks**: determination of the risks of the project and assignment in the contract of the responsibility of these risks to the parties.
- **Negotiation**: The type of contract should not be imposed but negotiated between the two parties and decided by common agreement.
- **Customer Requirements**: A turnkey project requires the customer to have an adequate and experienced technical structure to define their parameters, monitor their development, and approve and receive the works. If the client does not have their own technical and experienced staff, they should hire companies to provide such expertise.
- **Contractor Requirements**: The turnkey contract requires the successful bidder to have sufficient technical expertise and economic solvency in line with the size of the project. Companies should demonstrate that they have personnel, materials, and procedures with experience in similar contracts. It is common practice to train consortia between companies that are complementary in the distribution of jobs and the assumption of risks and responsibilities.
- **OBE phase**: Introduce into the procurement processes an estimation open book phase that allows for adjustments and agreed designs and prices, which will reduce the risks of the project, contingencies and construction phase deviations that result in costs and claims; this practice will have a better end result with a more transparent and fair treatment of the actual costs of the project.

It is clear that turnkey projects are more suitable to develop desalination plants which are multidisciplinary projects that include industry specific technological developments and require large investment budgets.

Although two desalination plants were chosen as a case study, this methodology applies to any other type of infrastructure project.

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**References**

1. Sanz, M.A. Trends in desalination & water reuse. In *Desalination and Water Reuse Business Forum. Enhancing Climate Resilience for Cities*; Singapore International Water Week: Singapore, 2018; Available online: [http://www.siww.com.sg/docs/default-source/default-document-library/mr-miguel-sanz.pdf?sfvrsn=2](http://www.siww.com.sg/docs/default-source/default-document-library/mr-miguel-sanz.pdf?sfvrsn=2) (accessed on 16 December 2019).

2. Spanish Association of Desalination and Reuse, AEDyR. *Desalination Figures in Spain*; AEDyR: Madrid, Spain, 2019; Available online: [http://www.aedyr.com](http://www.aedyr.com) (accessed on 16 December 2019).

3. International Desalination Association. *International Desalination Association and Global Water Intelligence Release New Data in 30th Worldwide Desalting Inventory*; IDA: Topsfield, MA, USA, 2018; Available online: [http://idadesal.org/international-desalination-association-and-global-water-intelligence-release-new-data-in-30th-worldwide-desalting-inventory/](http://idadesal.org/international-desalination-association-and-global-water-intelligence-release-new-data-in-30th-worldwide-desalting-inventory/) (accessed on 16 December 2019).

4. Olalde, K. The Engineering Contract; University of the Basque Country, Business Organization Department, Organization of the Project: Leioa, Spain, 2005; Available online: [http://www.ehu.eus/asignaturasKO/organizacion/organio9.pdf](http://www.ehu.eus/asignaturasKO/organizacion/organio9.pdf) (accessed on 16 December 2019).

5. Butlow, E.D. Real Estate Report; Buenos Aires, Argentina. 2005. Available online: [http://www.arquitectura.com/tecnica/legal/legislacion/butlow003.asp](http://www.arquitectura.com/tecnica/legal/legislacion/butlow003.asp) (accessed on 16 December 2019).

6. Ohrn, L.G.; Rogers, T. Defining Project Delivery Methods for Design, Construction, and Other Construction-Related Services in the United States; Northern Arizona University: Flagstaff, AZ, USA, 2008; p. 5.
7. Hernandez-Rodriguez, A. Los contratos internacionales de construcción “llave en mano”. In Cuadernos de Derecho Transnacional; Área de Derecho Internacional Privado Universidad Carlos III de Madrid: Madrid, Spain, 2014; Volume 6, pp. 161–235. ISSN 1989-4570.
8. Law 9/2017 on Public Sector Contracts (LCSP). Transposing into Spanish law the Directives of the European Parliament and of the Council 2014/23/EU and 2014/24/EU of 26 February 2014 (2018); No. 272; Official State Gazette: Madrid, Spain, 2017; p. 155. Available online: https://www.boe.es/buscar/pdf/2017/BOE-A-2017-12902-consolidado.pdf (accessed on 16 December 2019).
9. Jordan, P.T. Differences between EPC and design-build delivery. In Construction Law Blog Gordon Rees Scully Mansukhani; Gordon & Rees: San Francisco, CA, USA, 2015; Available online: https://www.lexology.com/library/detail.aspx?g=7e8d69d7-b936-4891-aab8-d69690c3cc71 (accessed on 16 December 2019).
10. International Federation of Consulting Engineers. Conditions of Contract for EPC/Turnkey Projects, 2nd ed.; FIDIC: Geneva, Switzerland, 2017.
11. Rahman, T. The Difference between EPC and Turnkey Contract; LinkedIn: Sunnyvale, CA, USA, 2016; Available online: https://www.linkedin.com/pulse/difference-between-epc-turnkey-contract-md-tanjir-rahman (accessed on 16 December 2019).
12. Jiyong, D.; Wang, N.; Hu, L. Framework for designing project delivery and contract strategy in chinese construction industry based on value-added analysis. Adv. Civ. Eng. 2018, 12, 1–14.
13. School of Industrial Organization, EOI. OBE Contracts Blog of the International Executive MBA in Infrastructure Sector Enterprises; EOI: Madrid, Spain, 2013; Available online: http://www.eoi.es/blogs/embacon/2013/05/22/contratos-obe/# (accessed on 16 December 2019).
14. Saracco, R. Desalination Plants Ask for Tech Evolution; IEEE: Piscataway, NJ, USA, 2019; Available online: https://cmte.ieee.org/futuredirections/2019/01/19/desalination-plants-ask-for-tech-evolution/ (accessed on 16 December 2019).
15. Martinez-Vallina, J.J. Environmental Impact Assessment of Desalinations; National Environment Congress, Sustainable Development Summit: Madrid, Spain, 2008; pp. 5–17.
16. Water Corporation. Southern seawater desalination project. In 2018 Performance Review Report; Water Corporation: Perth, Australia, 2018; p. 18.
17. Gransberg, D.D.; Koch, J.E.; Molenaar, K.R. Preparing for Design-Build Projects: A Primer for Owners, Engineers and Contractors; American Society of Civil Engineers ASCE: Reston, VA, USA, 2006; pp. 13–16.
18. Molenaar, K.R.; Songer, A.D. Selecting design-build: Private and public sector owner attitudes. J. Eng. Manag. ASCE 1996, 12, 47–53.
19. El-Wardani, M. Comparing procurement methods for design-build projects. In Computer Integrated Construction Research Program, Technical Report 45; Department of Architectural Engineering: University Park, PA, USA, 2004.
20. Thomsen, C.B. Developing, Marketing, and Delivering Construction Management Services, 2nd ed.; Construction Management Association of America CMAA: McLean, VA, USA, 2006.
21. U.S. Department of Transportation Federal Highway Administration. Design-Build Effectiveness Study—As Required by TEA-21 Section 1307(f); US DOT FHWA: Washington, DC, USA, 2006.
22. Touran, A. A Guidebook for the Evaluation of Project Delivery Methods; Transit. Cooperative Research Program, TCRP Report 131; Transportation Research Board: Washington, DC, USA, 2009; Available online: https://www.watercorporation.com.au/-/media/files/residential/water-supply/desalination/ssdp/ssdp-performance-review-report-2018.pdf (accessed on 16 December 2019).
23. Cleland, D.I.; King, W.R. System Analysis and Project Management; McGraw-Hill College: New York, NY, USA, 1983.
24. Royal Legislative Decree 2/2000 of June 16. Which Approves the Consolidated Text of the LAW on Contracts of Public Administrations; Official State Gazette: Madrid, Spain, 2000; Available online: https://www.boe.es/buscar/doc.php?id=BOE-A-2000-11533 (accessed on 16 December 2019).

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