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Governing business in the seawater desalination sector through terotechnology

Ahmed Abdulrahim Abuouf[a,*], Khalid Mohamed Al Habib[b], Meshal Hassan Hamdi[c]

[a]*Saline Water Conversion Corporation, Kingdom of Saudi Arabia, email: aabuouf@swcc.gov.sa*
[b]*Water Transmission and Technologies Co., Kingdom of Saudi Arabia, email: kalhabib@wttco.com*
[c]*Pacific Green Technologies Saudi Arabia, Kingdom of Saudi Arabia, email: meshal.hamdi@pacificgreen.tv*

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ABSTRACT

The business sector of seawater desalination is composed of three major sectors in the MENA Region and worldwide: public sector, private sector and public–private partnership (PPP). Regardless of the desalination process wither it is based on thermal principles or reverses osmosis principles, the terotechnology had approved itself as a key tool in controlling the whole life-cycle of the process from asset management point of view. The terotechnology which is composed of seven major phases including specification, engineering, manufacturing, installation, commissioning, operation and maintenance and finally the asset obsoleteness or replacement, can be used as tools to govern the desalination business in all its three forms. The objective of this paper is to illustrate how to implement this in practice; how to govern the desalination business through terotechnology, and will be supported with real cases from the public sector, private sector and the PPP sector from independent water and power producers cases wither it is build-own-operate-transfer (BOOT or BOO).

Keywords: Desalination; Governance; Life cycle costing; Privatization; Public–private partnership; Terotechnology

1. Introduction

1.1. Problem description

Luckily, both the Privatisation Concept and the terotechnology were initiated and started from the United Kingdom (UK). Although, they were tackling the same problem, but, from different approach and point of view; "Improving the Overall Economy Efficiency". Generally speaking, the privatisation is considered to be the upper-stream approach; Form of Business Model, Management, Finance and Legal. Whereas, the terotechnology is considered to be the down-stream approach; engineering, procurement, contracting, operation & maintenance and asset obsoleteness & replacement. However, both of them; the privatisation and the terotechnology, are cross-related and are completing each other. Both of them are having mutual relation controlling the whole-life asset costing related to the desired efficiency. In fact, this relation could be clearly understood if we review the history and the time-line of the evolvements of both concepts.

In the following paragraphs and figures, we will illustrate the evolvement of both concept and show the mutual relation between them; "Look at the Big Picture". First, the concept of terotechnology was initiated and started in the UK since 1970, as illustrated in Fig. 1. According to Kelly [1], the definition of terotechnology evolved between 1970 and 1975. In 1968 PA Management Consultants were commissioned by the then Ministry of Technology to carry out a study of engineering maintenance in British Manufacturing Industry. It reported that:

i. The total direct cost of engineering maintenance in British Manufacturing Industry was approximately £1,100 million/annum (value circa 1968).

* Corresponding author.

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ii. Improved productivity of maintenance staff could have led to a reduction in maintenance expenditure of around £250 million/annum.
iii. Better maintenance could have saved about £300 million/annum of lost production caused by unavailability.

Using this and other information, a Ministry of Technology working party reported in 1970, and emphasized, among other things, the importance of the link between maintenance costs and the feedback of information to the designers of plant. A steering committee (The Committee for Terotechnology) was set up in 1970 to examine the broader findings of this report and in 1972 published their conclusions, central to which was the statement:

The nature of the maintenance activity was determined by the manner in which plant and equipment was designed, selected, installed, commissioned, and operated removed and replaced. Major benefits could come to British Industry from the adoption of a broadly based technology which embraces all these areas, and because no suitable word existed to describe such a multidisciplinary concept, the name 'Terotechnology' (based on the Greek word terein — to guard or look for) was adopted. In 1975, the Committee for Terotechnology defined terotechnology as follows; 'A combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life cycle costs'.

The following was then added: 'its practice is concerned with the specification and design for reliability and maintainability of plant, machinery, equipment, buildings and structures, with their installation, commissioning, maintenance, modification and replacement, and with the feedback of information on design, performance and costs' [1].

The concept of terotechnology had been heavily considered in the period of 70's and beginning of 80's in the UK and worldwide. Many papers and academic and industrial researches have been conducted and there were conferences about terotechnology. Until, the introduction of the approach of "Privatisation" in the begging of 80's by Margret Thatcher as it attracted the general attention of the community toward the change of industrial general shape, as illustrated in Fig. 2. Then, the Concept of Privatisation evolved in the period of 80's. After the 1979 elections Thatcher became Prime Minister, she adopted the approach of privatisation to turn around this development of increased government intervention. Her motivation was claimed to be as follows:

- The post-war consensus
- Industrial relations
- Relative economic decline
- Share of world manufactured exports (%): as it decreased from 25.5% in 1950 to 9.1% in 1979
- GDP growth over 5-y periods in UK (%): as it decreased from 15.2% in 1950–1955 up to 9.3% in 1975–1980
- Inflation and unemployment in the UK, 1969–1979:
  - Annual inflation (%) increased from 5.4 in 1969 up to 13.4 in 1979
  - Total unemployed (millions) increased from 0.597 in 1969 up to 1.390 in 1979
  - Unemployment rate of total labour force (%) increased from 2.5 in 1969 up to 5.7 in 1979

Thatcher claimed that one of the main principles of Thatcherism was the privatisation of industry in order to roll back the frontiers of the state [5]. We here in this paper, will not argue the advantages and disadvantages of the approach, but to illustrate the progress of the approach through the time-line and history with the terotechnology.

William Megginson and Jeffrey Netter define the political and economic policy of privatisation as the deliberate

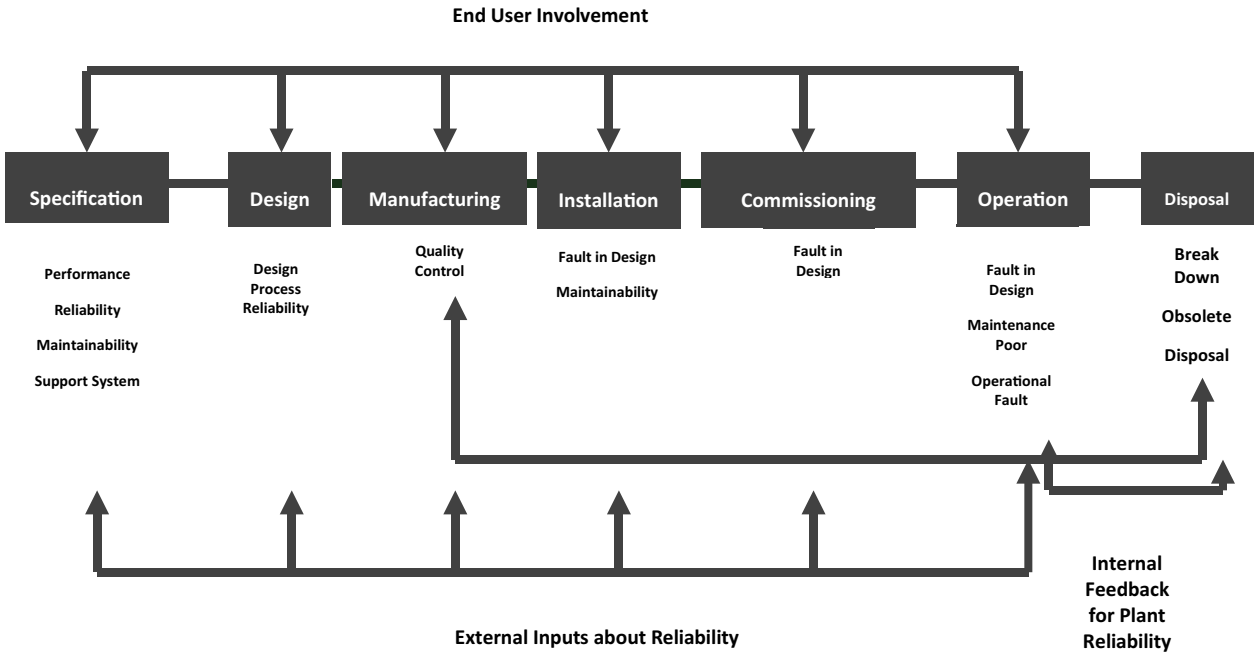

Fig. 1. Terotechnology in brief – the optimization of total maintenance costs over the equipment's life-cycle.

Down-stream management			Time	Up-stream management		
Terotechnology				Privatisation		
	International	UK		UK	International	
Let the Machine Work			1945-1955	Before 1945 all services & assets were private sector owned		Private Sector Ownership
				After 1950 all services were transferred to state ownership		
Optimise Process			1955-1965		Dec 1960 The Organization for Economic Co-operation and Development (OECD)	State Ownership
		1967 government noticed of decrease in efficiency	1965-1970			
		1973 Terotechnology concept	1970-1980	The economy of socialists		
	1978 German translation	Terotechnology conferences				
		Terotechnology periodical		1979 election of Thatcher		
			1980-1990	The privatisation concept (idea formulation)		The Privatisation Program
				British Privatisation Program		
				1981 British aerospace 51.6%		
				1982 Britoil 51%		
				1984 British Telecom 50.2%		
				1986 British Gas 97%	1986-88 France, Jacques Chirac privatised 22 companies	
				1987 British airports authority 100%		
Optimise Business		1993 BSI dependability system	1990-2000		1990 Italy, Germany and Spain start privatisation program	
	Sweden, Växjö University Terotechnology College	1998 Manchester University Master in Maintenance Engineering & Asset Management				
		2008 BSI 15686 life cycle costing	2000-2010	2008 Combined Code was published on the Financial Reporting Council website	2009 OECD corporate governance	Business Governance
		2008 BSI 3845 Guide to Terotechnology		2013 Margaret Thatcher passed away	2013 The Economist Thatcherism	
Industry 4.0	2010 ISO 55000 Asset Management – Overview, principles and terminology		2010-2020	2018 FRC announced the publication of a revised UK Corporate Governance Code	2019 OECD Guide to privatisation policy maker	

Fig. 2. Terotechnology, privatisation and corporate governance history in UK and worldwide [1,3,6,10].

sale by a government of state-owned enterprises (SOEs) or assets to private economic agents [5]. This definition will be the one used for this chapter. The objectives for the British privatisation programme: [9].

1. Raise revenue for the state
2. Promote economic efficiency
3. Reduce government interference in the economy
4. Promote wider share ownership
5. Provide the opportunity to introduce competition
6. Subject SOEs to market discipline

Objective four, promoting wider share ownership among the population, became very important for the Thatcher government. Very important in that objective of achieving this 'Capital-Owning Democracy' was the privatisation of the state telephone system into British Telecom in November 1984. It was symbolic for the shifting balance from production to the consumer in the economy and would be considered the real breakthrough for privatisation [6].

Objectives of privatization; It was not until 1983 that the then Financial Secretary to the Treasury first stated what the objectives of the privatization program were. Among the prominent ones which can be identified are: (1) Reduce government involvement in the decision making of industry; (2) Permit industry to raise funds from the capital market on commercial terms and without government guarantee; (3) Raise revenue and reduce the public sector borrowing requirement (the PSBR); (4) Permit wide share ownership; (5) create an enterprise culture; (6) Encourage worker share-ownership in their companies; (7) Increase competition and efficiency; (8) Replace ownership and financial controls with a more effective system of economic regulation designed to ensure that benefits of greater efficiency are passed onto consumers.

Its real objective, it is argued, is to finance government expenditures through the sale of state assets [5]. However, the privatisation approach had been accepted by the community and policy maker in the UK and spread in Europe and all over the world since the 90's.

Consequences of privatisation; A major criticism on privatisation comes that the enhanced productivity of the privatised firms was because the CEOs had made them 'leaner' and 'fitter' by reducing the workforce [4]. It was expected that privatisation would lead to increased performance of the privatised companies. Stephen Martin and David Parker have done several studies on the effects of privatisation on the performance of eleven British companies privatised during the period 1981–1988 and analysing the changes in several features of the companies over the course of privatisation. These were the rate of return on capital employed, annual growth in value-added per employee-hour, labour productivity growth and total factor productivity growth. The outcome was mixed. Half of the studied firms did not have outright performance improvements after privatisation. They highlight the run-up to privatisation as most influential on improvements in performance, leading to the conclusion that the 'threat' or 'opportunity' of privatisation may lead to improved performance because it 'gels management'. It also demonstrates that performance improvement is possible under public ownership 'when the incentive and will exist'. These mixed results confirm for them that 'privatisation does not guarantee good performance' [6]. According to the Asian Development Bank's (ADB), "public–private partnership (PPP) Handbook, there are many forms of public–private partnerships; the build-own-operate-transfer (BOOT) option, Does not necessarily improve efficiency of ongoing operations; May require guarantees [2].

In the 2003, The Financial Reporting Council became responsible for the UK Corporate Governance Code. The Smith Report was published in the wake of the collapse of Arthur Andersen and the Enron scandal. The report concerned auditor independence, and provided guidance for audit committees. The Higgs Independent Review considered the role and effectiveness of non-executive directors. In the 2008, The Combined Code was revised and renamed the UK Corporate Governance Code. Following 2009, the Organization for Economic Co-operation and Development (OECD) issued OECD Corporate Governance. Lately in 2018, FRC announced the publication of a revised UK Corporate Governance Code.

Corporate governance is the system of rules, practices, and processes by which a firm is directed and controlled. Corporate governance essentially involves balancing the interests of a company's many stakeholders, such as shareholders, senior management executives, customers, suppliers, financiers, the government, and the community. Since corporate governance also provides the framework for attaining a company's objectives, it encompasses practically every sphere of management, from action plans and internal controls to performance measurement and corporate disclosure [5].

In the 1993, the first British Standard issued for the terotechnology. "1993 BSI Dependability System". Later on 2008, the BSI issued 2008 BSI 15686 Life Cycle Costing and the 2008 BSI 3845 Guide to Terotechnology. Worldwide, in 2011 the International Standard Organization issued the ISO 500001 Energy Management System.

1.2. Setting objectives

The main objective of this paper is to discuss the controlling of the whole-life asset cost related to the desired efficiency and the optimization of total operation and maintenance costs over the equipment's life-cycle in the sea water desalination sector through integrating the Terotechnology System into the Business Governing System and Code, as illustrated in Fig. 3.

1.3. Proposed solution

The main criterion for measuring the success of the investment is to assure the achievements of the various goals of all business stakeholders through the need of business governance and business optimization. Of course, there are many forms of business model such public sector, private sector and public–private partnership. Setting the goal and objective in the last model (the public–private partnership – PPP) considered being the most complicated one. Thus, the guarantee of the success in this model needs more attention and this why we will focus on it in the rest of this paper.

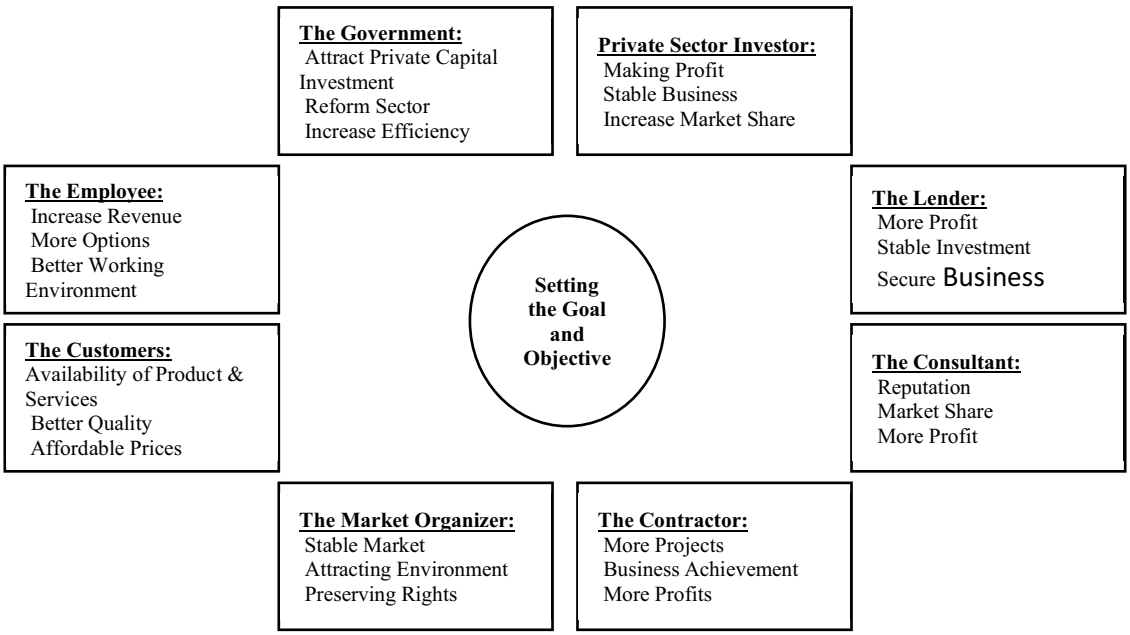

Fig. 3. Setting the goal and objective of the various business stakeholders.

The three main needs that motivate governments to enter into PPPs for infrastructure are:

- to attract private capital investment (often to either supplement public resources or release them for other public needs);
- to increase efficiency and use available resources more effectively;
- to reform sectors through a reallocation of roles, incentives, and accountability;

According to the Asian Development Bank's (ADB), "Public–Private Partnership (PPP) Handbook [2], there are many forms of public–private partnerships such as follows:

- service contracts
- management contracts
- lease contracts
- concessions
- BOT/BOO/BOOT

We will focus on this paper on the build-own-operate-transfer (BOOT) option, as it is Investment in and operation of a specific major component, such as a desalination plant. As illustrated in Fig. 4, the public–private partnership capital projects for the independent water and power producers (IWPP) is composed of the two sectors; the public sector and the private sector to form a partnership and passes through four main phases:

- Creation of the technical investors consortium
- Creation of the special purpose company or vehicle
- Creation of the plant
- Start of the production through operation and maintenance activities

Of course, every phase composed of many stages. We will not go through every stage of these stages in details, however, what is important to us the figure of the start of the creation project assets and the stages that it will pass through.

The public–private partnership with the BOOT option passes through many distinctive phase as illustrated in Fig. 4:

- Developing the framework of the PPP
- Investment proposal announcement
- Technical investor consortium creation
- The bidding process
- The public–private partnership signing contracts and agreements
- The special purpose company creation
- The plant creation which is usually done through EPCM project
- The EPCM projects contracts
- The operation and maintenance contracting
- The exit/entry of the business and the end and termination of the project

Usually, the life cycle of the investment takes from 30 to 35 y long. The responsibility for each of the above stages varies from public sector to privates sector in each stage.

Privatization involves the sale of shares or ownership in a company or the sale of operating assets or services owned by the public sector. Privatization is most common and more widely accepted in sectors that are not traditionally considered public services, such as manufacturing, construction, etc. When privatization occurs in the infrastructure or utilities sectors, it is usually accompanied by sector-specific regulatory arrangements to take account of social and policy concerns related to the sale, and continuing operation of assets used for public services.

IWPP		Public sector	Public private partnership	Private sector	Asset
Technical investors consortium creation	Success of Transformation	Demand/ Supply			
		Feasibility studies		Investment proposal	
		Legalization		Feasibility studies	
		Government guarantee		Loan/ financing	
		Bidding start		Investor agreements	
		Concept report		Financial closure	
		RFP invitation		Investor consortium	
Special purpose company creation				Bidding	
				RFP submission	
		RFQ invitation		RFQ submission	
		Quotation analysis			
		Successful bidders			
		PPP contract	SPC creation	PPP contract	
Plant creation	Success of performance improvement		EPC project invitation		
			Bidder invitation		Specification
			RFP invitation		Engineering
			RFQ invitation		Manufacturing
			Contracts signing		Installation
Production operation maintenance start			Commissioning		Commissioning
			Operation activities		Operation and maintenance
			Maintenance activity		
			Procurement activity		
			Financial activities		

Fig. 4. Setting the goal and objective of the various business stakeholders.

According to Kelly [1]:

- The plant operator should co-operate with the designer/ manufacturer/installer in a full analysis of its reliability, maintainability and safety characteristics. Such a 'plant procurement' exercise should include assessment of spare-part provisioning, of maintenance personnel training and of supplier support systems. The higher the potential costs of maintenance and unavailability the more vital is this exercise.
- Decisions to buy new or replacement equipment should be based on a present-value life-cycle analysis of costs. Such an analysis must take into consideration both maintenance and unavailability costs — these being estimated, wherever possible, from documented experience.
- The plant operator and supplier should co-operate in the collection and analysis of plant failure and maintenance data in order to identify maintenance problem areas and to determine the plant's optimum maintenance operation. Since the design of equipment is a continuing process, information thus gathered should, ideally, be continuously fed back to the equipment manufacturer, and in certain circumstances to a data bank, which could be shared on an intercompany, national or international basis. The difficulties of these last operations continue to pose a major obstacle to the successful implementation of a Terotechnological approach, communication systems are expensive and different organizations (with different objectives) are involved during the equipment life cycle" [1].

We need a system that track and document the creation of the plant from its early stage; asset-by-asset, as illustrated in Fig. 5. Nowadays, there are many companies for building enterprise resource project such as Oracle and SAP had succeeded in developing ERP systems that cover many aspects of the investment projects such as:

- Business modelling
- Capital budgeting

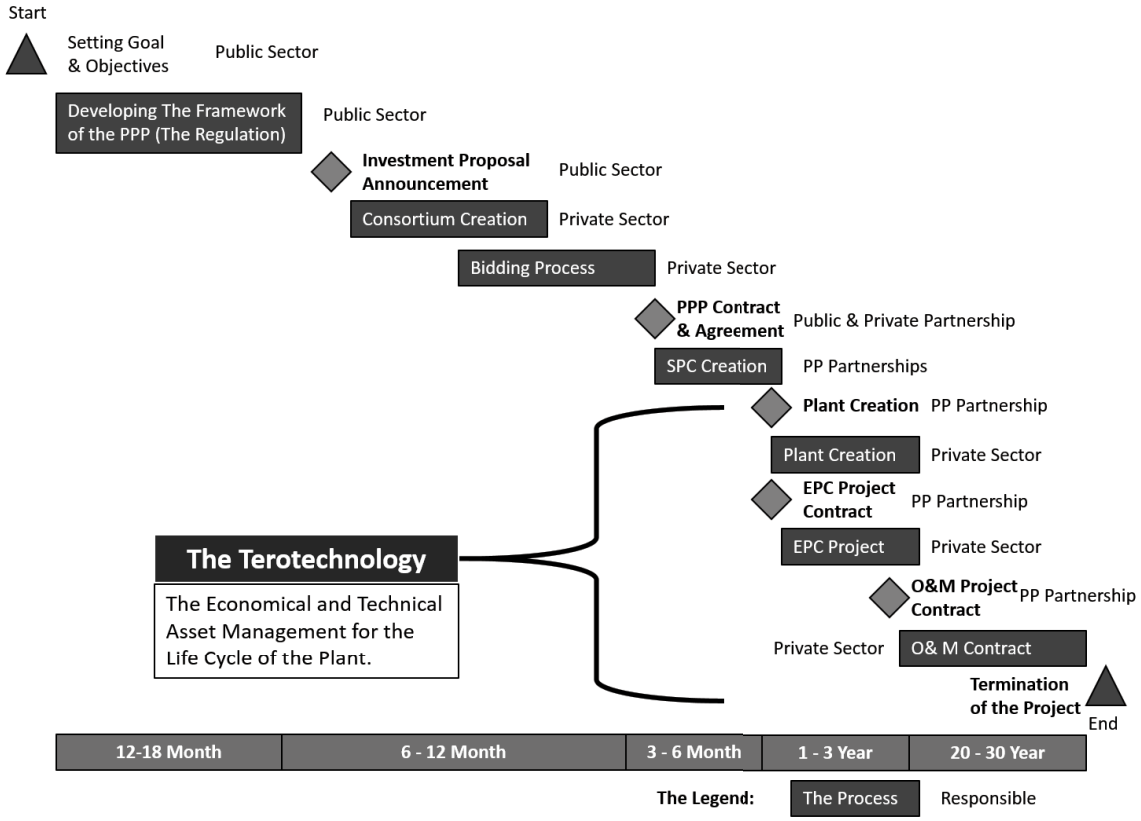

Fig. 5. Terotechnology location on public–private partnership projects (BOOT).

- Procurement
- Installation
- Operation
- Maintenance

Which all covers the life cycle of the assets and could suite the implementation of the terotechnology, as illustrated in Fig. 6.

Typical elements of an asset management system implemented compose of the following:

- Asset management
- Preventive and condition-based maintenance
- Collection plans
- Work management
- Work order
- Planning and scheduling
- Work execution
- Stores management
- Maintenance cost management
- Budgeting and forecasting

Enterprise asset management enables the customer to (1) Drive maintenance best practices and improve your organization's performance; (2) Empower all workers with easy to use self-service (web and mobile) applications; (3) Manage the full asset lifecycle with a complete view of your assets and equipment; (4) Replace costly stand-alone maintenance systems with integrated solution; (5) Support compliance and corporate governance with an enterprise perspective. The methodology of how to apply the model of the terotechnology physically in real world business through ERP is in the following steps:

- Align the business strategy with operation and maintenance strategy by choosing the proper maintenance strategy
- Transfer all the recent engineering concept derived from the various maintenance strategy in asset management into practical policies and procedures
- Included all of these policies and procedures in the Rule Book for Governing the business
- Adopt these guide lines in the Rule Book for governing the business in the ERP System

The operation and maintenance strategies had to be matched with business strategy of the project. Definitely, the maintenance part is having a remarkable significance as it is affecting the cost of the project directly and indirectly. It is very important to transform the newly engineered concepts of maintenance models into policies and procedures. Benefits of the approach of implementing terotechnology physically through ERP System will be of great help into practicing the governing of the business, preserve the rights of the various stakeholder of the business, and ease the tracking of the potential area for applying business and process optimization.

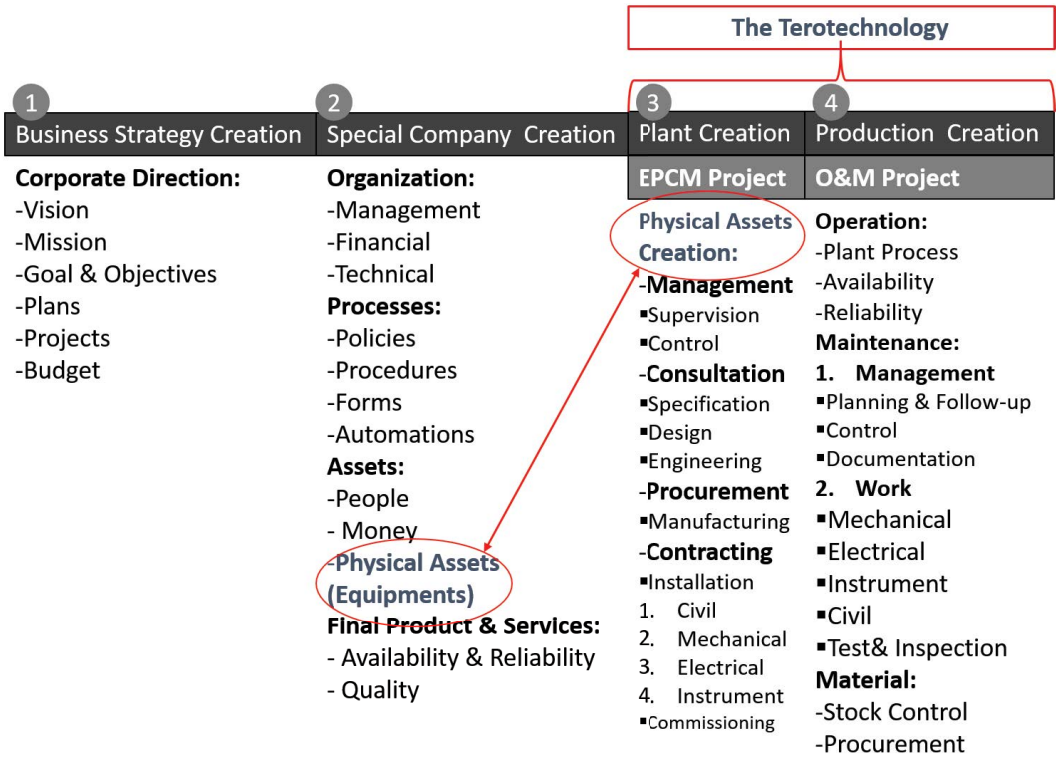

Fig. 6. Why terotechnology fits in public–private partnership projects (BOOT) option.

1.4. Evaluation

The final evaluation of the process will in comparing the final result gained from the final outcome of the project with the goals and objectives sated up from the early stage of the project by the stakeholder of the project, as illustrated in Fig. 7. Of course, this is process of comparison is repetitive and should be done phase by phase of the project.

The most important action to reach the gap between the sated goals and objectives is continuous assessment of the hall project. Here the good command of the business governance and business optimization will play a remarkable role in narrowing the gap between the result gained and the objectives and goals of the project.

The most challenging part of the BOOT project is that; it composes of many phases and detailed stages and every stage has its interdisciplinary crew and people from technical to financial, administrative, and legal sometimes, which presents the need of system thinking approach to adopt the hall project and its inter-process.

2. Methodology

2.1. BSI (2008)

The British Standard Institute had issued BSI PAS 55:2008 for Asset Management as guide for terotechnology implementation.

2.2. Terotechnology in practice

According to Levy [7], the general structure of the relationship among all stakeholder of the project is illustrated in Fig. 8 as each relation between two stakeholders are covered by a special kind of agreement. The main player here is the Special Purpose Company or sometimes is called a vehicle. The key stakeholders are as follows:

- The government
- The lenders
- The shareholders
- The off-taker or final product purchaser
- The consultants
- The construction contractors
- The suppliers

Finally, the key player here is the operator as the heavy load of successes of the project will be hold on his back and will take the responsibilities of the major risks of the project.

3. Results

For example, an oil company is attempting to map out the costs of an offshore oil platform. They would use terotechnology to forecast the exact costs associated with assembly, transportation, maintenance, and dismantling of the platform and finally a calculation of salvage value. The study and application of terotechnology is not an exact science, as there are many different variables that need to be estimated and approximated. However, a company that does not use this kind of study may be worse off than one that approaches an asset's life cycle in a more ad hoc manner. Terotechnology uses such financial analysis tools such as net present value (NPV), internal rate of return

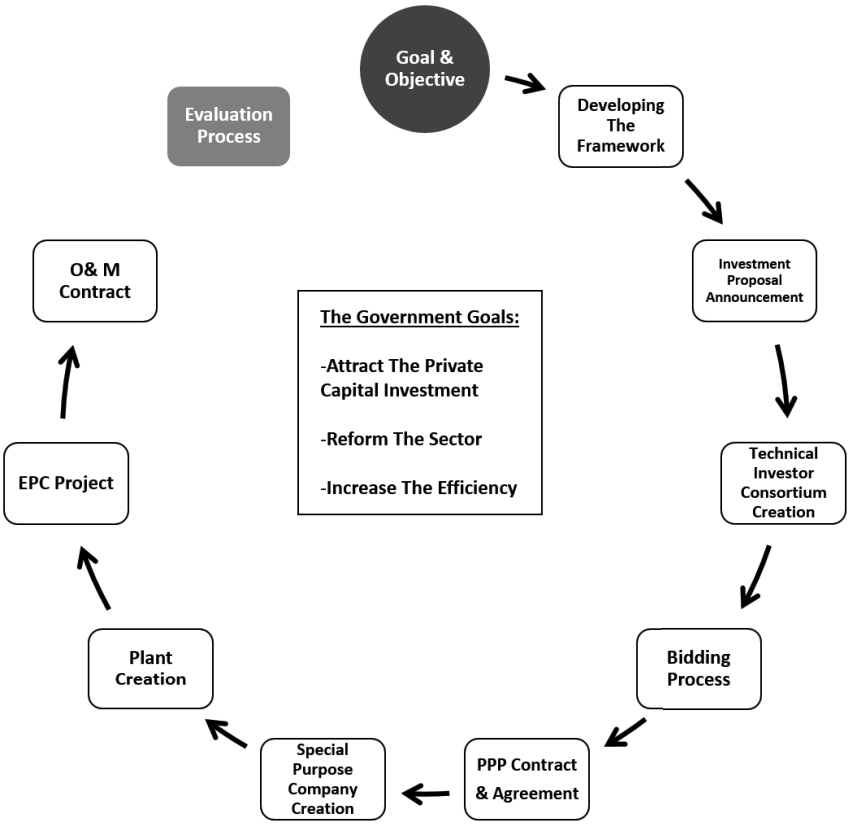

Fig. 7. Evaluation and the assessment process (reaching the gap).

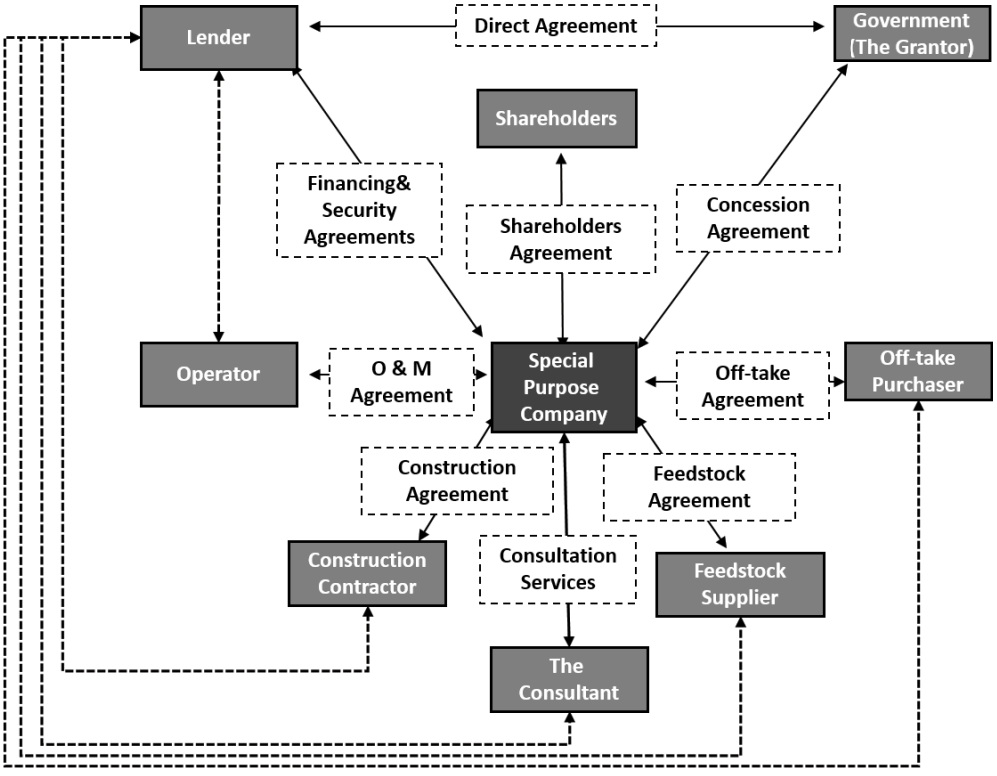

Fig. 8. Public–private partnership stakeholder's relationship & contractual agreements [7].

(IRR), and discounted cash flow (DCF) in an attempt to minimize the costs associated with the asset in the future. These costs can include engineering, maintenance, and wages payable to operate the equipment, operating costs, and even disposal costs. Decisions related to each of these costs are taken in consideration with the twin objectives of optimizing the equipment's operations and costs associated with it. As illustrated in Table 1, we do have two kind of plants; green field asset meaning new plant and brown field asset meaning plant in-use. Due to the criticality of the subject could find plant from the private sector to participate with information of applying the terotechnology as it is considered to be kind of industrial secrets. The return on investment here is playing a major role.

4. Discussion

4.1. Need of terotechnology guide in the desalination sector

In order to implement terotechnology in the desalination sector, we need to create a guide; "terotechnology guide for implantation". It is defined as framework and standard for measuring quality in the area of asset management. Fortunately, there are two international standards available to refer to:

- BSI PAS 55:2008 – the international benchmark for optimal management of assets
- ISO 55000 series comprise of ISO 55000, ISO 55001 and ISO 55002

The difference between the two standards, BSI PAS 55:2008 focus on the physical assets whereas ISO55000 is a standard for any asset type. In fact, even though these standard are good start, however, we need to a detailed guide to implement terotechnology in the desalination sector.

4.2. Need of terotechnology hub

There are many Institute locally and worldwide concerned with the subject of excellence of asset management, for example:

- The Institute of Assets Management, UK
- The International Standard Organisation, ISO55000, USA
- Centre for Cost-effective Industrial Asset Management, Sweden
- Centre of Excellence in Maintenance (CEIM), Kingdom of Saudi Arabia

However, in order to be able to implement terotechnology in the desalination sector, we need to have a hub that will enable the collaboration between the diverse stakeholders of the desalination business. Luckily, we do have the International Desalination Association, internationally and Water Science and Technology Association, regionally in the Kingdom of Bahrain that can enable the address of the terotechnology system and concept in the sector.

5. Conclusion

5.1. Terotechnology as a system

Terotechnology is a combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life cycle costs. Focuses on whether an asset is owned, managed and utilized in such a manner to create and/or sustain its value profile defined by its stakeholder. Its practice is concerned with the specification and design for reliability and maintainability of plant, machinery, equipment, buildings and structures, with their installation, commissioning, maintenance, modification and replacement, and with the feedback of information on design, performance and costs. It involved various kind of consultants, contractors, suppliers, engineers and manpower technicians. It also include various kind of discipline of engineers; chemical, mechanical, electrical, instrument, electronics, civil and industrial. Thus, it need to be treated

Fig. 9. Terotechnology as system and the requirement for its implementation [3].

Table 1
Green field and brown field asset

	Public sector	Public private partnership	Private sector
Brown field asset	Plant in-use	Plant in-use	Plant in-use
Green field asset	New plant	New plant	New plant

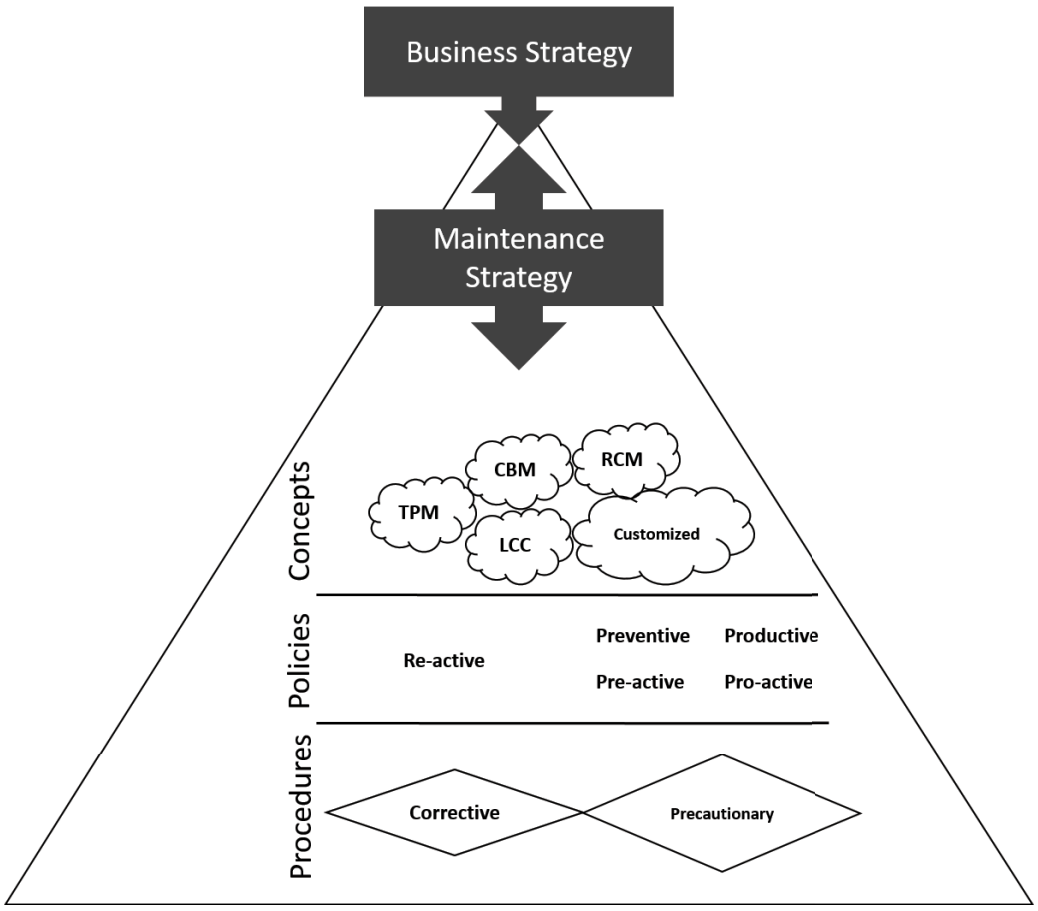

Fig. 10. Terotechnology implantation road map and plan in the desalination sector [8].

as a system. So, in either standard British Standard BSI PAS 55:2008 for Asset Management and the International Standard ISO55000 it required the System-Thinking type of people to work on it instead of the Reductionist-Thinking type of people. Someone who have the ability of being; holistic, systematic, systemic, risk-based, optimal, sustainable and integrated, as illustrated in Fig. 9.

5.2. Terotechnology implantation road map and plan in desalination sector

In fact as previously mentioned, the main objective of this paper is to discuss the controlling of the whole-life asset cost related to the desired efficiency and optimization of total operation and maintenance costs over the equipment's life-cycle in the sea water desalination sector through integrating the terotechnology system into the business governing system and code, as illustrated in Fig. 10.

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