Performance Measurement of Water Desalination Supply Chain Using Balanced Scorecard Model

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***Abstract*—The purpose of this study is to propose a theoretical framework based on a balanced scorecard (BSC) for performance measurement in the water desalination supply chain (WDSC). The reason for choosing this context is that the supply chain (SC) of water desalination has received a great amount of attention, due to issues related to the increased need of fresh water for agricultural, industrial and human consumptions. The research methodology is based on literature analysis concerning performance measurement and metrics, the water desalination industry and the BSC model. Different SC performance measures which related to WDSC have been reviewed and distributed into four BSC perspectives: financial, customer, internal business, and learning & growth. The article provides a structured theoretical framework specific for WDSC. This is the first developed framework in WDSC which could serve as a reference to develop applicable performance indicators, and it is expected that both researchers and practitioners would benefit from the proposed framework.**

Keyword- balanced scorecard, supply chain, water desalination, performance measurement.

I. Introduction

In the last two decades, companies realized that cost reductions or earning profit should not occur at the cost of their SC partners, but rather, through making the whole SC more effective [1]. The expression of "supply chain management" was primarily introduced in the early 1980s [2] and has acquired enormous concern afterward. SC is a network of materials, information and services processing connected with the attributes of supply, transmutation and demand [3]. Suppliers, focal manufacturing and customers are connected via information, materials and capital flows. Focal firms are those firms which rule the SC, deal directly with the customer, and design the provided product or service [4],[5].

Supply chain management (SCM) has developed dramatically for the last two decades, due to the increment in publications of SCM theories, models and practices [6]. As firms shift towards SCM, it becomes important to evaluate the SCs performance [7]. Performance measurement is fundamental to the prosperity of any organization since it builds comprehension, molds behaviour and enhances competitiveness [8]. Measuring SC performance helps for better perceiving, positively affecting SC partners'' behaviour and enhancing its overall performance [9].

In order to fulfil customer orders more quickly and efficiently, SC needs continuous improvements [10]. It needs an effective performance measurement to be developed and therefore, a performance measurement framework is required. Several researchers have proposed various measurement systems using the metrics of performance from different aspects [11]. As a matter of a fact, there is no one best way to manage all supply chains and different supply chains have to be managed differently. This is because supply chain performance is determined by various factors. Several studies proposed performance measurement frameworks for supply chain in different industries such as hospital laboratories SC, food SC, dairy SC, and furniture [12]. However, there is no performance measurement framework in the water desalination industries has been found. The initiatives of this research arise from the above observations.

The proposed framework provides a holistic view for water desalination supply chain to enhance its efficiency. The motive for selecting this context is that the SC of water desalination has received a large amount of concern, due to issues related to the increased need of fresh water for agricultural, industrial and human consumptions. Measuring the performance of water desalination supply chain is going to help managers to understand how their supply chain is performing now, and enable managers to make informed decisions and to take appropriate actions to improve the performance, so as to sustain their competitive advantages.

The outline of this article is as follows: Section 2 reviews the literature of measuring SC performance, balanced scorecard and water desalination. Section 3 presents a framework for measuring WDSC performance based on BSC model. Finally, the conclusion and future direction have been discussed.

II. BACKGROUND AND LITERATURE REVIEW

[13] views supply chain management as a process of associating several business entities consisting of suppliers, manufacturers, distributors, retailers and customers. These integrated entities are important in managing the flow of resources such as material flows (products, servicing, recycling), information flows (order transmission, tracking, and coordination of physical flows), and financial flows (credit terms, payment schedules, and consignment arrangements). As supply chains compete against supply chains, it is vital that they are managed effectively so as to enhance their performance. SC performance is the extent to which a SC satisfies consumers' needs regarding the relevant performance indicators at any time and at what total SC cost.

A. Supply Chain Management

The tremendous success of SCM in manufacturing and service industries makes it attractive to be adopted in water desalination industries. SCM has been significant topic in both manufacturing and business for the last three decades. Its contribution to achieve customer satisfaction and business success has been proved by several studies. Furthermore, SCM can enhance efficiency, and decrease the total operating costs.

The terms SC and logistics are used interchangeably. Nevertheless, logistics is derestrict to the motion of material, storage, and inventory management, whilst SC has a wider scope covering issues concerning purchase, partnerships, and customer satisfaction in addition to logistics issues [14]. Several researchers have used the term SC to make reference to value chain processes of a manufacturing company from purchasing and receiving of component, through the transformation processes of production, to distribute products to the manufacturer’s customers.

According to [15], the supply chain management processes exist in both service and manufacturing industries, despite the fact that the managerial complexity of the chain might differ greatly from industries and different firms. Since competitive advantage is now defined in terms of supply chains instead of single companies, it is imperative that supply chain performance are continually analysed to improve its performance hence increasing its competitiveness. The significance of SC analysis or SCM is proven by the large amount of research in the area. An excursion into the literature on supply chain analysis reveals that it is a multi-faceted area of research reflected by the multi issues discussed and the various different methodologies adopted.

SC of water desalination has received a substantial attention for the last few years, due to issues related to the increased demand for freshwater worldwide. Considering the desalination industry as a SC permits utilizing SC theories, models, and existing SC standards for performance measurement to enhance the overall efficiency (Al-Nory & Graves, 2013). Thus, this research is timely, relevant and can become a foundation for further theoretical developments in the scope of water desalination supply chain. Fig. 1. shows a schematic for basic activities of water desalination supply chain.

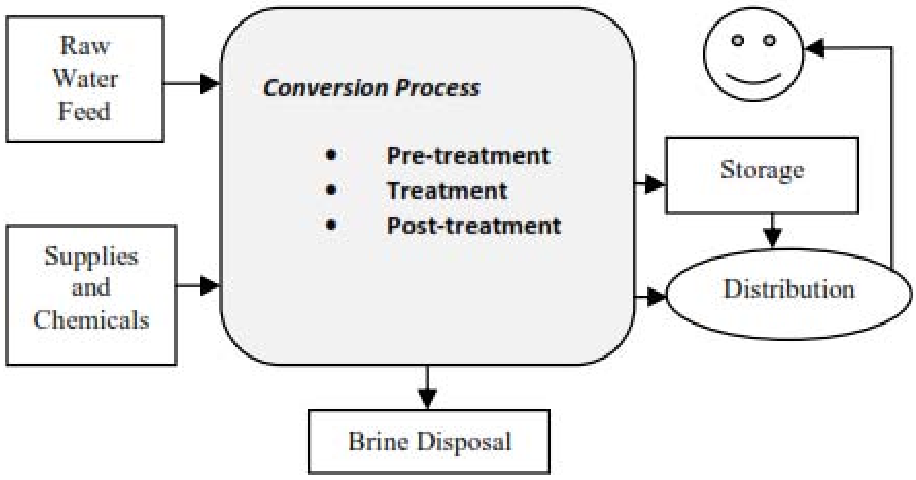

Fig. 1. A simplified example of WDSC [39]

B. Performance Measurement

Performance measurement is defined as the procedure of quantifying the efficiency and effectiveness of an activity, while a performance indicator is a measure employed to quantify the efficiency and effectiveness of an action [16]. Whilst there are numerous indicators of performance which could be used in a company, there is a related few number of crucial dimensions that contribute to success or failure in the industry, that are called key performance indicators. Measurement of the whole SC performance is significant because measuring SC performance affects decision making through the evaluation of previous behaviour and via benchmarking. According to [17], a Performance Measurement System (PMS) is described as a system which allows informed decisions to be made and actions to be taken since it quantifies the efficiency and effectiveness of previous activities by acquisitions, collation, sorting, analysis, interpretation and dissemination of adequate data. There have been relatively few endeavours to categorize performance measurement systems of SC in a systematic way. These systems have been classified in three groups that are mentioned frequently by other researchers as follows: hierarchical based, process based, and perspectives based approaches.

1) *Hierarchal based PMS:* Hierarchal based PMS evaluates SC performance through various hierarchical levels. Analyzing SC performance measures and metrics at the strategic, tactical and operational levels helps manager to make the right decisions. Furthermore, it permits achieving the overall objectives of an organization. Hierarchical PMS was first proposed by [11]. They proposed a framework in which metrics are classified into strategic, tactical and operational levels of management. The classification purpose was to allocate metrics to be dealt by the appropriate management level. The metrics were also categorized into financial and non-financial so that a proper costing method based on activity analysis can be applied. Financial indicators are most appropriate for the strategic level [18]. However, due to the large quantity of metrics presented in the framework, companies encountered difficulties in applying it. Furthermore, the framework does not provide guidelines to priorities the metrics. In another paper, [19] presented a performance measurement framework considering the four major supply chain processes (plan, source, make/assemble, and deliver). Metrics were also categorized into strategic, tactical and operational levels to identify the appropriate level of management authority and responsibility for performance. Metrics were grouped in cells at the intersection of the SC activity and planning level. Moreover, for prioritizing purpose, a score for each metric was given by three levels: highly, moderately, and less important level.

2) *Process based PMS:* Due to the significance of the operational dimension in SCM, understanding the activities and key processes of SC is essential to develop an efficient PMS. Researchers and practitioners have sought to develop new approaches which consider the performance of key operational processes in SC. [20] proposed dynamic framework to design the flow of information and material within SC. A process based approach consolidating bottom-up and top-down performance measures has been proposed by [21]. Six-sigma metrics were adopted by [22],[23] to develop their frameworks for evaluating the performance across the whole SC. A cross boundary process-based system was developed by [24]. In another paper, [25] investigated on the feasibility of PMS in SC using process based approach. Five core processes including: supplying, inbound logistics, core manufacturing, outbound logistics and marketing & sales were considered in their research. The process-based perspectives were employed to build an effective PMS to measure the holistic performance of complex supply chains. [19] proposed a framework based on the four main SC processes (plan, source, make/assemble, and deliver). Later on, [26] addressed the framework developed by [19] through several time periods in order to measure the efficiency of SC. [27] employed the Six Sigma: define, measure, analyze, improve and control (DMAIC) processes in their model for SC performance evaluation. Nevertheless, the mode lacks of covering the whole decision making levels.

A PMS to manage SC performance in a dynamic environment was proposed by [28]. [29] presented a SCPMS that measures the performance of key SC activities of a firm under several performance dimensions based on an extensive literature review. The nine key internal SC activities are the corner stone for the proposed framework. However, during the implication process, some of the required data were unavailable. [30] proposed a fuzzy type model based on various input factors treated as a linear membership function. The proposed PMS uses the fuzzy set theory and AHP for performance evaluation. A business process oriented PMS was proposed by [31] to solve the heterogeneity problems among partners in SC. Decisional and operational activities were both considered. Strong relationship between SC practices and performance metrics (i.e. total length, inefficiency ratio, and working capital productivity) has been proven by [32]. They developed a PMS for benchmarking in paint manufacturing SC and an empirical analysis has been done. However, other factors such as size of the company have been neglected. [33] investigated the effect of five SC practices (i.e. quality, time, information, flexibility, and integration) in SC performance. An empirical analysis in electronic manufacturing SC has been carried out. The results showed that information has the highest impact in SC performance comparing to other practices.

C. Balanced Scorecard Model

The BSC consist of four different perspectives of performance measures. Fig. 2. displays a scheme of the balanced scorecard model.

- *Financial perspective*. This perspective indicates the conventional requirement for financial data. Precise and timely funding data will consistently be a priority. Financial-related data, such as cost-effectiveness, are usually comprised in this perspective. However, an emphasis on financial perspective leads to the “unbalanced” condition with other perspectives.
- *Internal business processes perspective*. The objective of this perspective is to satisfy shareholders and customers through excelling in internal processes. Metrics under this perspective assist managers to be aware of the performance of business, and whether its products/services satisfy customer needs.
- *Customer perspective*. One of the main objectives of SCM is to meet customer needs. Low performance under this category is a significant indicator of decline in future, even though the present financial situation might appear good.
- *Learning and growth perspective*. This perspective aims to develop a long-term growth of the business. It contains manpower training and corporate cultural behaviors to both individual and corporate self-enhancement.

Fig. 2. Balanced scorecard model

Kaplan and Norton have developed the BSC approach as a tool for performance evaluation with four perspectives of financial, internal business process, customer, and learning and growth. The essential principle of the BSC is that standard financial measures must be balanced with nonfinancial measures. The development of performance measurement system related to the four perspectives of the BSC has been discussed in many articles [34],[35],[36],[37],[38].

The balanced scorecard model has been widely considered in the literature of supply chain management, however less or no attention has been paid to its adoption in water desalination industry. This is because the concept of water desalination supply chain was first introduced in 2013 by [39], which makes it relatively new. Some of performance measurement articles for SCM used the BSC perspectives in model/framework development. However, no specific studies addressed the development of a BSC model for the water desalination SC. Therefore, the objective of this research is to propose a balanced scorecard framework for performance measurement, delaminated for the water desalination SC.

D. Desalination Industry

Although water composes almost 71% of the globe, fresh water scarcity is one of the most significant issues worldwide. This is because oceans (saline water) hold about 97.5 percent of the whole water distribution, while fresh water accounts for 2.5 percent only. And, of the total freshwater, more than 68% is locked up in ice and glaciers. Another 30% of freshwater is ground water.

More than 20 percent of the population (1.2 billion people) worldwide lives in areas where physical access to water is limited. Arid regions are often correlated with physical water scarcity. On the other hand, more than 25 percent of the world's population (1.6 billion people) suffers from economic water scarcity. Economic water scarcity exists when a population does not have the substantial monetary techniques to extract an appropriate source of water. Sub-Saharan Africa is one of the most regions which suffer from economic water scarcity. It is important to mention that even countries which does not suffer from water scarcity nowadays, they might be affected in future due to climate changes, desertification, and the increased demand for water.

Desalination refers to a water treatment process which separates salts from water. It is also called desalting or desalinization. Fresh water production from brackish or seawater is the ultimate result of desalination regardless which treatment process or technologies was applied. Considering the fact that 97.5% of the whole water distribution in the world is saline water in oceans, this makes it clear that the existence of water desalination technologies to provide freshwater for drinking, farming, and industrial purposes is highly significant.

Over decades, there is a remarkable increase in the global demand for freshwater to satisfy the needs of growing populations and economies. A sharp increase in the number of desalination plants constructed worldwide is indicated. In 1980, desalination plants produce around 5 million m³/d of freshwater. This number increased to reach 52 million m³/d from 14,000 plants in 2008, while in 2012 it become 79 million m³/d from 16,000 plants globally. According to [40], the total capacity of desalination is expected to increase at annual rate of 9% for the period from 2010 to 2016.

Vast interest has been presented in the water desalination research to enhance the efficiency of a sole desalination plant. Nevertheless, less attention has been paid to assist in improving the performance of the entire supply chain of water desalination starting from acquiring seawater until delivering potable water to consumers. The term 'water desalination supply chain' has been firstly introduced by [39]. They stated that the importance of a supply chain perception originates from the ability of planning or optimizing at a system level rather than at a component or unit level. In fact, the supply chain perception attempts to avoid sub-optimization [39].

III. A FRAMEWORK FOR MEASURING THE PERFORMANCE OF WDSC

An intensive literature review, concerning SC, performance measurement and desalination SC was performed. The aim of the literature analysis was to examine the current available PMS for SCs, and to precisely analyze particular issues of the desalination SC, to determine key performance indicators (KPIs) to be employed in the performance evaluation. In specific, the four perspectives of the BSC model are the dimensions of the framework proposed in this study. As a result, a set of performance indicators appropriate to be adopted in the context of water desalination SC has been emerged.

Measuring the performance of water desalination supply chains is even more difficult, because WDSCs are different from other supply chains in some aspects (e.g. transport, processing, monitoring, storing). Qualitative performance indicators such as consumer acceptance of the product need to be taken into account along with other non-qualitative performance indicators [41]. The logistics of water supply attempt to imitative the natural flow of liquids, the river. From a logistics perspective, pipelines lessen the handling of individual units of the liquid since it is treated as a flow rather than as identifiable, discrete units [42].

The earlier discussion discloses the necessity for practitioners to measure WDSC performance through applying a few number of critical performance measures. Organizations which have numerous measures usually fail to realize that measuring performance with limited good measures would lead to a better evaluation [43]. As shown in Fig. 3, the proposed framework, by adopting the four dimensions of the BSC will shift the emphasis from operational to strategic considerations. Although the developed framework does not concentrate on detailed measurement procedures, it is proposed in conformity with the basics of systems thinking. For the purpose of clarification, the supply chain is seen as a whole entity, and the measurement framework spans across the whole WDSC. The developed framework addresses multi-dimensional perspective of WDSC performance. Therefore, it provides balanced, comprehensive performance evaluation.

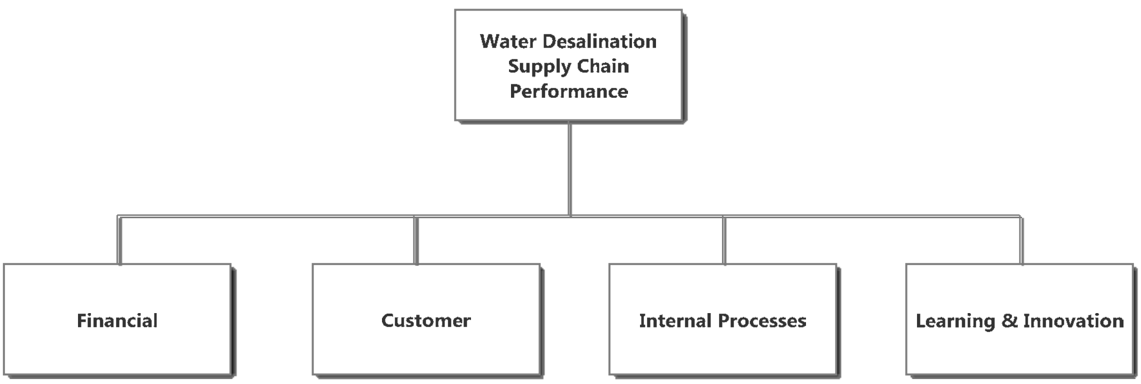

Fig. 3. The proposed framework for measuring WDSC performance

This framework is proposed to direct researchers' potential and provide awareness for managerial practice. The BSC for WDSC framework is identical to the BSC framework structure developed by Kaplan and Norton. However, in this paper, metrics which are specific to water desalination suggested with the intention to assess WDSC performance comprehensively. The different performance indicators for WDSC are fitted into four dimensions of BSC as shown in Tables 1–4. Every perspective along with its measure should reflect the strategic objectives for the firm in water desalination industry. Thus, the metrics should be reviewed annually and updated as needed. However, for assessing, it is advised that performance indicators are not used for periods shorter than one year, since this might lead to deceptive conclusions. In case of evaluating for shorter period of time, a special attention is needed in analyzing and external comparison should be avoided.

TABLE I. Performance indicators under the financial perspective

Financial Perspective
Revenue
Investment
Average water charges
Leverage
Liquidity
• **Capital costs:**
Depreciation costs
Net interest costs
• **Running costs:**
Manpower costs
Electrical energy costs
Treatment costs
Transmission, storage and distribution costs
Water quality monitoring costs
• **Profitability:**
Return on net fixed assets
Return on equity
Return on capital employed
• **Economic water losses:**
Non-revenue water by volume
Non-revenue water by cost

TABLE II. Performance indicators under the customer perspective

Customer Perspective
• **Service coverage:**
Households and businesses supply coverage
Population coverage
• **Customer complaints:**
Service complaints per connection
Service complaints per customer
Billing complaints and queries
Response to written complaints
• **Continuity of supply:**
Population experiencing restrictions to water supply
Water interruptions
• **Quality of supplied water:**
Aesthetic tests compliance
Microbiological tests compliance
Physical-chemical tests compliance
Radioactivity tests compliance
• **Water meter reading efficiency:**
Customer reading efficiency
Residential customer reading efficiency
Operational meters
Unmetered water

TABLE III. Performance indicators under the internal business processes perspective

Internal Business Processes Perspective
Efficiency of water distribution
Desalination plant utilization
• **Water storage:**
Raw water storage capacity
Desalinated water storage capacity
• **Pumping:**
Pumping utilization
Standardized energy consumption
Reactive energy consumption
Energy recovery
• **Transmission and distribution network:**
Valve density
Hydrant density
• **Inspection and maintenance of physical assets:**
Pump inspection
Storage tank cleaning
Active leakage control repairs
Mains rehabilitation
• **Operational water losses:**
Water losses per connection
Water losses per mains length
• **Service connection, meter installation and repair:**
New connection efficiency
Time to install a customer meter
Connection repair time

TABLE IV. Performance indicators under the learning & innovation perspective

Learning & Innovation Perspective
Reused supplied water
• **Personnel qualification:**
University degree personnel
Basic education personnel
Other qualification personnel
• **Personnel training:**
Internal training
External training
• **Automation and control:**
Automation degree
Remote control degree

As proven by practice, a system which works successfully in one organization could be a disaster in another one. There are different factors that determine what the water desalination supply chain should look like for any particular company. The proposed framework provides an efficient method to build the performance index. In order to construct a specific WDSC balanced scorecard for a firm, the following steps are recommended:

(1) Define the organization objectives and strategy for each of the BSC dimensions. This is because the significance of each measure and perspective are based on the adopted strategy for organization.

(2) Prioritize performance dimensions and performance indicators to be corresponded with the firm's adopted strategy. This is due to the impossibility for a supply chain to achieve excellence in all aspects.

(3) Develop a preliminary balanced WDSC performance measurement system based on the defined objectives and strategy of the organization.

(4) Receive feedbacks and comments on the preliminary PMS from the stakeholders, and modify it accordingly.

(5) Obtain a consensus on the WDSC PMS which would be applied by the organization.

(6) Demonstrate the balanced WDSC PMS to all stakeholders for evaluation purpose.

IV. CONCLUSION

The increasing significance of SCM has engendered a large number of disjointed researches across different disciplines. Performance measurement is a fundamental factor for effective planning, control, and decision-making. Although there were many researchers emphasized on the importance of measuring SC performance, there is a lack of a comprehensive framework to measure the supply chain performance in water desalination industry. The scientific evolution of a coherent SCM discipline requires a progression in developing theoretical frameworks to further enhance our understanding of water desalination supply chain phenomena.

In this article, based on a literature review, different performance measurements of SC have been discussed. This study has considered the use of a BSC model with specified metrics to measure and evaluate water desalination supply chain performance. The research framework developed in this paper provides a well-grounded and solid foundation for theoretical development of alternative models, along with their impact on water desalination SC performance. Specific metrics have also been developed for each of the four dimensions. While adopting the BSC model in WDSC, it is interesting to notice that some of the performance indicators in one perspective might contradict other indicators in another perspective. Even within a perspective, one WDSC performance indicator might compromises others. The main outcome of the study is the development of a set of performance indicators embodied into a BSC-based tool for measuring performance in water desalination supply chain context.

This study has significant practical implications. Managers would make better decisions which will result in enhanced the companies' overall performance. The BSC perspectives and their related performance indicators are considered as a template rather than an integral WDSC PMS. Nonetheless, the proposed framework can be used to detect and evaluate specific operations and general performance enhancement efforts. A guideline has been presented to show how the developed framework and its performance indicators could be applied in real life. To examine whether the adopted perspectives and metrics are needed and sufficient, further studies are recommended. Finally, future studies are also necessary to validate the proposed BSC framework and to examine its suitability for desalination industry.

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