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A conceptual Framework for Supply Chain Performance in Desalination Industry

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Abstract

Academic and corporate interest in sustainable supply chain management has risen considerably in recent years. In this article, a conceptual framework is proposed for measuring supply chain (SC) performance in water desalination industry. The research methodology is based on literature analysis concerning performance measurement and metrics to be applied for companies belonging to the water desalination industry. Since the study focuses on a specific industry, this could be considered as a limitation of the work as the results presented are not suitable to be generalized or extended to other contexts, although some extrapolations can be made. The paper provides the first conceptual performance measurement framework specific for the water desalination supply chain. The proposed framework could serve as a reference for the desalination industry to establish applicable performance appraisal indicators. It is believed that both researchers and practitioners would benefit from the framework developed.

Key words: *Performance measurement, supply chain, desalination, sustainability*

1. INTRODUCTION

Supply chain management (SCM) has strategic effect for supply chain partners. It illustrates the discipline of enhancing the delivery of goods, services and information from raw materials supplier up to the end customer. Recently, manufacturers have been highly affected by social and environmental requirements [1]. Thus, proper attention is needed to incorporate these aspects in SC strategies. Effective sustainable management strategies facilitate evaluating, enhancing and controlling the performances of SC operations.

SCs consist of several stages, namely supplier, manufacturer, distributor, and consumer which influence each other performance. A very significant issue in SC environment for practitioners is that they know where a product is now, how it got here and where will it be in the future [2]. Hence, the development of integrated performance measurement framework is a significant topic in SCM. A performance framework supports establishing performance measures by identifying measurement dimensions, and might also provide initial anticipation into relationships among the different aspects [3], [4]

Many researchers have proposed different measurement models using the metrics of performance from different perspectives [5]. [6] concern with environmental performance as an operation's objective, where SC issues are only secondarily discussed. In a similarly study, the authors centred their research on green product development [7]. While, [8] focused on the intersection of environmental topics with logistics. The articles in the field of 'Sustainable Operations Management' published in 'Production and Operations Management' have been reviewed by [9]. Individual issues related to SC have been discussed with limited insight on the holistic research in the field. Several studies proposed performance measurement frameworks for SC in different industries such as hospital laboratories SC [10], agri-food SC [11], food SC [12], dairy SC [13], furniture [14]. Although a good number of studies have been reported in the literature, there is a lack of involving the measurement of green performance in water desalination supply chain (WDSC) [15]. Existing performance measurement frameworks disregard social, environmental and sustainable aspects [16]. Thus, a holistic framework which can be implemented in water desalination supply chain is proposed in this study. On the basis of the above considerations, this study aims at developing a conceptual framework based on balanced scorecard (BSC) model with some modifications. These modifications are

necessary to make the framework more sustainable and proper to be implemented in the water desalination supply chain. Moreover, this paper demonstrates how a sustainable framework for WDSC can be implemented.
The article is organized in the following sequence. Section 2 illustrates a background based on a systematic literature review regarding SC performance measurement. The next section elucidates the proposed framework. The last section concludes the paper and indicates the scope for further studies.

2. LITERATURE REVIEW

Supply chain management has been viewed as a process of associating several business entities consisting of suppliers, manufacturers, distributors, retailers and customers [17]. 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 [18].

2.1 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 [19].
According to [20], the supply chain 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 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 [21]. Thus, this research is timely, relevant and can become a foundation for further theoretical developments in the scope of water desalination supply chain. Figure 1 shows a schematic for basic activities of water desalination supply chain.

2.2 Performance measurement

[22] interpreted performance measurement 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. 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 [23]. Measurement of the whole SC performance is significant because measuring SC performance affects decision making through the evaluation of previous behaviour and via benchmarking. There are several performance measurement systems (PMS) have been developed for SCM. They can be categorized as hierarchal and horizontal PMS.

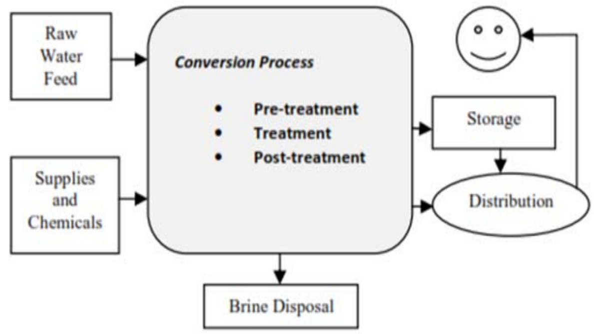

Figure 1. A simplified example of WDSC [21]

2.2.1 *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 [19]. 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 [24]. 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, [25] 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.
[26] employed process hierarchy and considered different SC stages: function-based, process, and supply chain levels in their PMS. [27] presented an innovative performance measurement approach including five core processes: supplying, inbound

logistics, core manufacturing, outbound logistics and marketing & sales. [28] revisited the work of [27] with aim of proposing a more user-friendly PMS by using fuzzy logic technique. Thus, the model was a combination of two existing PMSs: Chan and Qi's model and the (SCOR) model. These two PMSs complete each other in measuring SC performance.

[29] classified the performance indicators for SC into three categories related to management abilities: ambition, reality and facility. [30] proposed a hierarchal based PMS in order to analyse the performance of safety, health, environment and risk (SHER) consultancy service supply chain (SSC) in India. An empirical study developed by [31] in the manufacturing industry to develop a hierarchical based PMS for Green Supply Chain (GSS). [32] proposed a PMS to help managers to select the most suitable interoperability solution in a given context. To demonstrate the applicability, the benefits and limitations of their PMS, an empirical case has been applied in the French aerospace sector. Four criteria were considered: human resource, budget, risk and cultural gap. Lastly, a comparison among the four selected criteria has been applied for different scenarios to select the best option.

2.2.2 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. [33] proposed dynamic framework to design the flow of information and material within SC. [34] viewed supply chain as a set of processes to evaluate different SC designs and carried out a case study in mobile communication industry. A process based approach consolidating bottom-up and top-down performance measures has been proposed by [26]. Six-sigma metrics were adopted by [35] to develop their frameworks for evaluating the performance across the whole SC. A cross boundary process-based system was developed by Chan and Qi (2003a). In another paper, [36] 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. [27] proposed a framework based on the four main SC processes (plan, source, make/assemble, and deliver). Later on, [37] addressed the framework developed by [25] through several time periods in order to measure the efficiency of SC. [38] 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.

The SCOR model was introduced in 1996 including five main processes including plan, source, make, deliver, and return [39]. Furthermore, it contains several performance metrics used in conjunction with five performance attributes: reliability, responsiveness, flexibility, cost, and asset attributes. The SCOR model links performance metrics, best practices and software requirements to a detailed business process model [40]. [16] proposed a framework for the empirical analysis of SCPMS with a single case study of involving automotive industry in UK. Nevertheless, further empirical research is required to validate the proposed framework. A framework to study the effect of information sharing, on-time delivery rate and total cost in a supply chain was developed by [26]. The performance factors include capacity tightness, resource reliability, and information sharing modes were selected and tested via simulation. Additional element could be included in future since the study focused on information sharing capability.

[41] adopted a process-oriented SCOR model to identify the performance measures and the KPI in their PMS. They also investigated interdependent relationships among a set of KPI to improve SC performance. [42] presented a method for aggregating multi-level metrics with respect to their dependencies. They utilized the SCOR model performance measure to evaluate the efficiency of each level and covered the SCOR model attributes. [43] considered the overall performance of supply chain and proposed a process based framework based on the SCOR model. [44] proposed a PMS using the SCOR model for describing the involved sub-system processes. The authors applied Choquet integral for handling interactions between systems and processes. [45] developed a PMS focusing on agility perspective for distributors in pharmaceutical SC. Agility practices lead to provide the right product, at the right time to the customer. The proposed PMS is based on SCOR model to evaluate the agility performance in SC.

2.3 **Desalination**

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. Figure 2 shows the percentage of water distribution worldwide.

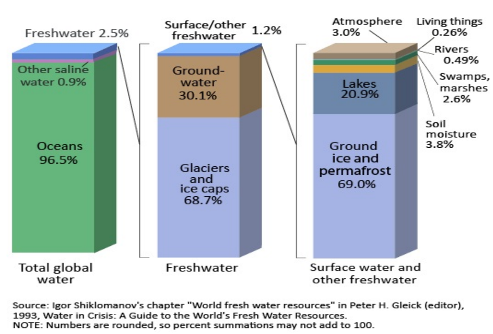

Figure 2. Global water distribution

More than 20 percent of the population (1.2 billion people) worldwide lives in areas where physical access to water is limited [46]. 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 [46]. 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 m^3/d of freshwater. This number increased to reach 52 million m^3/d from 14,000 plants in 2008, while in 2012 it become 79 million m^3/d from 16,000 plants globally [47]. According to [47], 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 [21]. 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 [21].

3. SUSTAINABLE WATER DESALINATION SUPPLY CHAIN FRAMEWORK

An intensive literature review, concerning SC, performance measurement, sustainable management and desalination SC was performed. The aim of the literature analysis was to examine the current practice for WDSC, and to precisely analyse sustainability issues of the desalination SC, to come out with suitable performance metrics. In specific, four perspectives of the BSC model are the base dimensions of the framework proposed in this study. However, environmental and social dimensions are included while learning &innovation perspective is excluded since some studies showed its inefficiency. As a result, a set of performance indicators appropriate to be adopted in the context of water desalination SC has been emerged.

Sustainable products are referred to all types of products that have improved environmental and social standards. 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 [48]. [49] suggests; "it is critical therefore to focus management attention on the performance of the SC as an integrated whole, rather than as a collection of separate processes or companies". Many authors, such as [50], [36], and [25], appear to agree with [49].

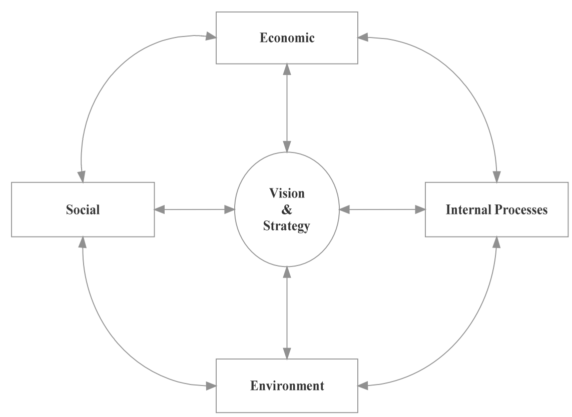

Figure 3. shows the percentage of water distribution worldwide

As shown in Figure 3, the proposed framework is intended to guide researchers' potential and provide awareness for sustainability practices. Metrics which are specific to water desalination have been developed with the intention to assess the sustainable WDSC performance comprehensively. The different performance indicators for WDSC are fitted into four dimensions i.e. economic, social, environment and internal business processes 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 1. Performance metrics developed for measuring water desalination supply chain performance

Internal business processes perspective	**Social perspective**
Efficiency of water distribution	•Service coverage
Desalination plant utilization	Households and businesses supply coverage
•Water storage	Population coverage
Raw water storage capacity	•Customer complaints:
Desalinated water storage capacity	Service complaints per connection
•Pumping:	Service complaints per customer
Pumping utilization	Billing complaints and queries
Standardized energy consumption	Response to written complaints
Reactive energy consumption	•Continuity of supply:
Energy recovery	Population experiencing restrictions to water supply
•Transmission and distribution network:	Water interruptions
Valve density	•Quality of supplied water:
Hydrant density	Aesthetic tests compliance
•Inspection and maintenance of physical assets	Microbiological tests compliance
Pump inspection	Physical-chemical tests compliance
Storage tank cleaning	Radioactivity tests compliance
Active leakage control repairs	•Water meter reading efficiency:
Mains rehabilitation	Customer reading efficiency
•Operational water losses:	Residential customer reading efficiency
Water losses per connection	Operational meters
Water losses per mains length	Unmetered water
•Service connection, meter installation and repair:	•Personnel training:
New connection efficiency	Internal training
Time to install a customer meter	External training
Connection repair time	
•Automation and control:	
Automation degree	
Remote control degree	

Economic perspective	**Environment perspective**
Revenue	Water utilization
Investment	Energy utilization
Liquidity	Materials utilization
• Capital costs:	Chemicals discharge
Depreciation costs	Pollution generated
Net interest costs	Process waste
• Running costs:	Airborne emissions
Manpower costs	Brine and chemical disposal
Electrical energy costs	Greenhouse gas emission
Treatment costs	Carbon footprint
Transmission, storage and distribution costs	•Airborne emissions:
Water quality monitoring costs	CO_2 emissions
• Profitability:	NO_x emissions
Return on net fixed assets	NMVOC emissions
Return on equity	SO_x emissions
Return on capital employed	

5. CONCLUSION

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 an extended 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. The main outcome of the study is the development of a set of performance indicators embodied into economic, environment, social, and internal business processes dimensions.

The conceptual performance framework aids in making decisions of the manufacturing firm regarding the overall organizational goals. This study has significant practical implications. Managers would make better decisions which will result in enhanced the companies' overall sustainable performance. A guideline has been presented to show how the developed framework and its performance indicators could be applied in real life. Finally, future studies are necessary to validate the proposed BSC framework and to examine its suitability for desalination industry.

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Konceptualni okvir za performanse lanca nabavke u industriji desalinizacije

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Primljen (19.08.2015.); Recenziran (22.11.2015.); Prihvaćen (10.05.2016.)

Rezime

Akademski i korporativni interes za menadžment održivog lanca snabdevanja značajno je porastao poslednjih godina. U ovom radu, konceptualni okvir se predlaže za merenje performansi lanca nabavke u industriji desalinizacije vode. Metodologija istraživanja zasniva se na analizi literature koja se bavi merenjem i metrikom performansi koje se primenjuju kod kompanija koje pripadaju industriji desalinizacije vode. S obzirom na činjenicu da se studija fokusira na specifičnu industriju, to može da se posmatra kao ograničenje rada, jer rezultati koji su predstavljeni nisu pogodni za generalizaciju ili proširenje na druge kontekste, iako neke ekstrapolacije mogu da se naprave. Rad pruža prvi konceptualni okvir merenja performansi koji je specifičan za lanac snabdevanja desalinizacije vode. Predloženi okvir može da posluži kao referenca za industriju desalinizacije kako bi se ustanovili primenljivi indikatori dobrih performansi. Veruje se da i istraživači i praktičari mogu da imaju korist od razvijenog okvira.

Ključne reči: *merenje performansi, lanac snabdevanja, desalinizacija, održivost*