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The integrated framework for analysis of electricity supply chain using an integrated SWOT-fuzzy TOPSIS methodology combined with AHP: The case of Turkey

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A B S T R A C T

This paper proposes an integrated framework for analysis of an electricity supply chain using an integrated SWOT-fuzzy TOPSIS methodology combined with Analytic Hierarchy Process (AHP). The paper is divided into two main sections. In the first main section, the integrated framework comprising a qualitative framework and a quantitative framework is presented. In the qualitative framework, a general structure and so-called advanced planning framework are developed for an electricity supply chain based on the literature review in supply chain management (SCM). Then, a quantitative Strengths–Weaknesses–Opportunities–Threats (SWOT) framework is used to formulate a strategy plan based on the elements from the proposed qualitative framework. Since a qualitative SWOT analysis can be insufficient to formulate an action plan, an integrated SWOT-fuzzy TOPSIS methodology combined with AHP is proposed to prioritize the defined SWOT factors and to formulate a strategy plan with top priorities. In the second main section, the integrated framework is illustrated with the case of electricity supply chain in Turkey.

1. Introduction

SCM is a value chain management from the supplier of a supplier to the customer of a customer of a company with the aim of attaining an overall value. A rich literature is available in SCM [1–5]. A holistic view to end-to-end processes is the core value of the SCM concept enhancing overall optimization rather than sub-optimization of processes.

An electricity supply chain is a significant supply chain incorporating the processes from the primary fuel sourcing to electricity consumption. Since, electricity is a highly perishable commodity, a holistic view of processes with proper supply chain design becomes particularly invaluable to avoid any electricity losses. Considerable research has been conducted in the electricity supply chain. Bayod-Rujula [6] examined the consideration of a large number of distributed small generators in an electricity supply chain and presented innovative concepts such as microgrids and virtual utilities. Bouffard and Kirschen [7] explored the current state of research on centralized and distributed electricity systems and discussed the future of a hybrid system integrating the advantages of both systems. Forgionne and Guo [8] proposed optimal production and inventory policies for a centralized supply chain and adapted the policies to the electric utility supply chain. Gutiérrez-Alcaraz and Sheblé [9] proposed a dynamic game-theoretic model by using discrete event system simulation to consider the interactions among different players in an electricity supply chain. Odenberger and Johnsson [10] investigated the role of CO_2 capture and storage technologies for CO_2 emission reduction in an electricity supply chain. Peças Lopes et al. [11] discussed the key issues and challenges with respect to the integration of distributed generation to an electricity supply chain. Slingerland [12] examined the relationship between energy conservation and organization of an electricity supply chain by analyzing three case studies of energy conservation. Zhijun and Kuby [13] proposed a model for simultaneous consideration of supply side and demand side investments in an electricity supply chain. As evident from the examples, although the literature in the electricity supply chain is considerably rich, most papers focused on a few issues of the supply chain and there is a lack of an integrated framework considering different dimensions of an electricity supply chain.

The contribution of this paper is threefold. As a significant supply chain, an electricity supply chain could benefit from the concepts introduced in SCM literature. With this regard, as a first contribution, a *qualitative framework* is proposed for a better understanding of an overall view of an electricity supply chain and its elements by adapting the concepts defined in SCM literature. In this framework, the general structure of an electricity supply chain is defined and so-called advanced planning framework defined in SCM literature is adapted to the electricity supply chain. Advanced planning is a hierarchical and modular-based planning approach to design a whole supply chain for different planning

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horizon. Stadtler and Kilger [14] provided the general concept and modules of advanced planning and illustrated the advanced planning projects with case studies. Typical modules of an advanced planning framework are strategic network planning at long-term level, master planning at midterm level and production planning and scheduling at short-term level [15]. In an advanced planning system (APS), all modules are integrated with each other by an input or feedback relationship. The motivation for proposing advanced planning approach for an electricity supply chain is that this approach systematically covers different planning levels in an electricity supply chain and has a potential of integrating a wide variety of conceptual models and mathematical approaches introduced in electricity supply chain literature. Although the literature is rich in mathematical approaches and conceptual models proposed for different sections of electricity supply chain, it is not systematic and integrated, and advanced planning approach is aimed at addressing this gap in the literature.

The second contribution of the paper is that it proposes a *quantitative framework* for development of a strategy plan for an electricity supply chain. In this framework, SWOT factors are derived from the elements of the proposed qualitative framework. SWOT analysis is a structured approach to evaluate an organization with respect to its internal and external environment. By identifying factors in a SWOT matrix, action plans can be developed to augment strengths, eliminate or minimize weaknesses, exploit opportunities and identify threats. However, a qualitative SWOT matrix can be insufficient in many cases with no prioritization of SWOT factors. With this regard, the so-called quantified SWOT analysis has been proposed in the literature. The first quantified SWOT methodology, so-called A'WOT, included AHP integration and has been proposed by Kurttila et al. [16]. Other papers also appeared to illustrate A-WOT applications [17–19]. As an extension to SWOT-AHP integration, Yüksel and Dagdeviren [20] proposed Analytic Network Process (ANP) to be integrated with SWOT analysis. Other quantified SWOT techniques have also been proposed with or without uncertainty considerations [21–23]. However, the application of quantified SWOT methodology in energy planning has been relatively scarce [24]. The literature in integrated SWOT-TOPSIS methodology has also been very limited [25]. In this paper, an integrated SWOT-fuzzy TOPSIS methodology combined with AHP is proposed to structure and prioritize the SWOT factors for an electricity supply chain. AHP approach is used for determining the relative importance of factors within each SWOT group as well as the relative importance of factors across SWOT groups, while fuzzy TOPSIS is used for evaluating an electricity supply chain with respect to SWOT factors.

The third contribution of the paper is that the proposed qualitative framework and quantitative framework are illustrated with the case of electricity supply chain in Turkey. The current state of electricity supply chain in Turkey is outlined and a strategy plan is developed following the steps given in the qualitative and quantitative framework.

The paper has been organized as follows: In Section 2, the integrated framework proposed in the paper is outlined and detailed. In Section 3, the electricity supply chain in Turkey is evaluated with respect to the proposed methodology given in Section 2. Finally, in Section 4, conclusions and potentials for next research are discussed.

2. The integrated framework proposed in the paper

The integrated framework proposed in this paper is outlined in Fig. 1. Based on the literature review in SCM concepts and conceptual models, a general structure and advanced planning framework are developed for an electricity supply chain. Then, key factors are defined from the general structure and advanced planning framework as SWOT factors and these SWOT factors are incorporated into the integrated SWOT-fuzzy TOPSIS methodology combined with AHP for formulating a strategy plan.

2.1. Developing a general structure for an electricity supply chain

Based on the literature review in SCM, an electricity supply chain can be defined as a cross-company approach that incorporates the upstream and downstream integration of the processes and coordination of the electricity, information and financial flows from the supplier of the supplier to the customer of the customer of a company with the aim of maximizing overall value to all society (adapted from [2,26,27]). Overall value to all society can be attained by maximizing system reliability measures including adequacy and security of electricity supply, while minimizing total costs including an adverse effect to the environment (adapted from [28]). In system reliability measures, adequacy of supply refers to the ability of a system to supply electricity under normal conditions, while security of supply refers to the dynamic response of the system to unexpected events [28]. The general structure of an electricity supply chain comprises different elements, which will be detailed in the next subsections:

2.1.1. The overall long-term strategy of an electricity supply chain

The overall long-term strategy of an electricity supply chain can be defined as maximizing system reliability measures, while minimizing total costs across the supply chain.

2.1.2. Core processes in an electricity supply chain

The core processes in an electricity supply chain are primary fuel sourcing, electricity generation, electricity transmission, electricity distribution and electricity consumption [29]. The adaptation of the well-known Supply Chain Operations Reference (SCOR) model to electricity supply chain is provided in Fig. 2. During the transmission process, the electricity is drawn by transmission grids operating at a very high voltage, while during the distribution process, the electricity is distributed by regional grids operating at a low voltage [29]. The electricity consumption process includes also retailing process [29].

2.1.3. Internal environment of an electricity supply chain

The internal environment of an electricity supply chain represents the environment within companies or between the companies. Strengths and weaknesses with respect to internal

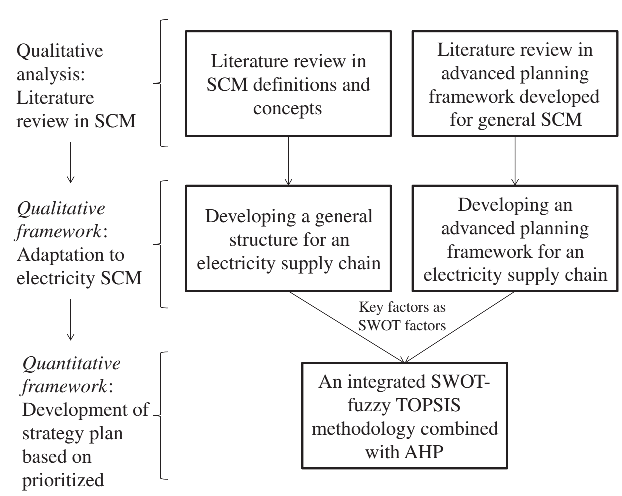

Fig. 1. The integrated framework proposed in the paper.