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Review

Downstream oil supply chain management: A critical review and future directions

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ABSTRACT

The oil industry has been playing a particular role in the modern economy, acting globally in different countries within competitive business environments. Due to the complexity of the oil supply chain, the associated decision making process is a difficult task, which involves numerous elements from oil supply, going through oil refining, up to oil product distribution. Thus, decision-support tools are often required to assist the decision making in the context of the oil supply chain. The improvement of such decision-support tools is a continuous goal for corporations. From this background, this work aims to review the scientific production about the application of mathematical programming techniques to the distribution problems, faced by diverse entities in the downstream oil supply chain. The main objectives are to point out main contributions, besides identifying the major voids and new trends in order to establish an agenda for future research directions.

Contents

1. Introduction

In the literature, there is no agreement about the supply chain definition, but the core of all definitions addresses the integration among entities and activities throughout the business processes which are developed over the network (Sahebi et al., 2014). Here, supply chain is understood as a complex and dynamic system, within collaborative or competitive environment, whose entities may or not cooperate to fulfill customer requests for products or services, where information, product and financial flows occur among different echelons over the time horizon. Therefore, the supply chain management arises to cope with this complex environment in order to plan, manage, coordinate and integrate all entities and activities by pursuing to accomplish customer requests, while striving for high revenues and low costs across the chain. In this way, Simchi-Levi et al. (2003) emphasize supply chain management as being a set of approaches to efficiently integrate the entities to organize all activities involved in fulfilling orders in the right quantities, right locations and on time so as to minimize the overall costs, while satisfying the service level requirement.

One special type of supply chain comes from the petroleum industry due to its size, its complexity, besides its economic and

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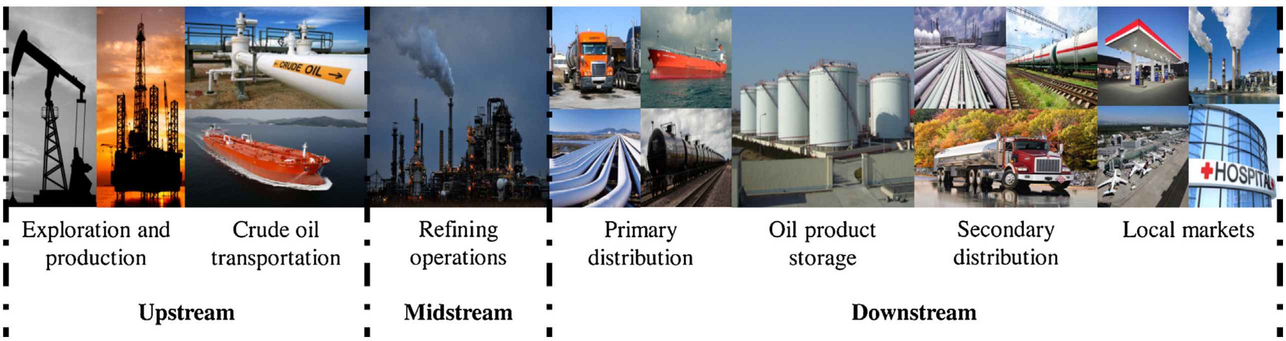

Fig. 1. The oil supply chain.

social importance. From 2010 onwards, the global oil production and consumption along with the global trade of crude oil and refined products have increased again in accordance with the data released by the British Petroleum (2015). However, in the petroleum industry, the revenues are as large as the overall costs, such as costs of exploring, producing and supplying crude oil, as well as costs of refining, distributing and marketing the refined products, as argued by the American Petroleum Institute (API, 2015). Additionally, the oil supply chain is inserted in an unstable context, influenced by geopolitical unrest, global competition and price volatility, where the business focuses on margins and the savings are carried out through improved forecasts and schedules with shorter planning horizon. As a result, the seek for designing and implementing new tools aims to establish an integrated and adaptive supply chain in order to improve the decision making process, reduce costs, decrease inventories and enhance margins (Capgemini, 2008). Moreover, the integration is a powerful way to lead the companies to the optimization of their value chain, while enabling them to balance their upstream and downstream activities, besides mitigating risk and reducing volatility (Ernst and Young, 2012).

According to Rice and Caniato (2003), a secure and resilient supply chain is a system enabled with security processes and procedures, while it is capable to proactively respond to diverse disruptions and restore its original operations. Christopher and Peck (2004) go further and add the capability of moving to a new and more desirable state after disturbances. In turn, resilient supply chains with higher capacity of mitigating risks are sought by the oil companies, where the resilience could be improved by different ways, e.g., through flexibility and redundancy. However, there exists a trade-off between the cost of developing it and its benefits to the network (Deloitte, 2010). Thus, the concept of resilience must be taken into account when designing and planning the supply chain to improve the capability to respond rapidly and cost-effectively to unpredictable events (Cardoso et al., 2015). Within this context, the optimization of the supply chain is a need to guarantee profitable, resilient and efficient systems. Such need has been addressed by the academic community and optimization tools have been developed and applied to better support the decision making process across such chain, by allowing and improving its management (Oliveira and Hamacher, 2012b).

It has been a long discussion whether the oil supply chain is divided into two or three segments, being the allocation of refinery operations the center of the discussion. As described by Sahebi (2013), the oil supply chain can be classified into three different classification schemes. The first considers the oil supply chain divided between upstream and downstream segments, incorporating the refinery and petrochemical plants within downstream segment. However, the second divides the network into upstream, midstream and downstream segments, where the midstream part comprises the refinery and petrochemical operations. Lastly, the third also considers the oil supply chain divided into three segments, but the midstream part refers to crude oil transportation to terminal and storage facilities. For the objectives of this literature review, the second classification scheme is more adequate, where the oil supply chain encompasses a set of functions which can be divided into three main segments, namely: upstream; midstream; and downstream – Fig. 1.

Then, the upstream segment comprises all functions from petroleum exploration, production and transportation until the refineries. The midstream concerns about the conversion of the petroleum into refined products at refineries and petrochemicals. Lastly, the downstream segment includes storage, primary and secondary distributions and marketing of refined products. In each segment, there are petroleum companies which rely on physical infrastructures across the network to develop these functions (Fernandes et al., 2014). Thus, Sahebi et al. (2014) list and classify the major facilities that compose the infrastructure into each segment as follows: in upstream, wellhead, well platform, production platform and crude oil terminal; in midstream, refinery and petrochemical industries; and then, in downstream, primary and secondary transport, storage depot and wholesale & retail market.

As in any typical supply chain, the decisions can be classified within strategic, tactical or operational levels, depending on its frequency and the time that it affects the network. The strategic planning is related to decisions with long-lasting effects that define the structure of the supply chain, what restrains the tactical planning, where the medium-term decisions concern to identify the best flow of material across the chain, besides establishing the operating policies in the operational level, that copes with short-term decisions related to scheduling of the activities (Chopra and Meindl, 2007), such as multiproduct pipeline scheduling and vehicle routing in the downstream segment, as well as any operational activities in the upstream and midstream segments (Barbosa-Póvoa, 2014). Each one of these decision levels must consider uncertainty over the decision horizon. Furthermore, the level of uncertainty changes over these planning stages, where it begins to decrease according to the decreasing of the decision horizon across the supply-chain planning. In short, there is a natural hierarchy among these stages, where the strategic planning imposes limits to the tactical planning, which in turn is implemented via operational level, while their mutual analysis and optimization are needed as well as their integration to improve the supply chain performance, as outlined by Al-Qahtani and Elkamel (2010a).

According to Grossmann (2005), the enterprise-wide optimization (EWO) aims to integrate the information and the decision-making along the supply chain through developing analytical information technology (IT) tools, based on mathematical programming, while seeking to improve the optimal economic performance. Thereby, EWO focuses on major operations and activities in the process industries (e.g., oil industry) in such way to reduce costs and inventories. However, the lack of optimization