Design of the hydrogen supply chain

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Research environment

In the research unit OPERA (“Optimisation Et Réseaux”, for Optimization and networks), the proposed topic fits into the Logistics axis. In this area, we are working particularly in Operations Research, around exact methods, metaheuristics and multi-objective optimization for transport integration in the supply chain, at various levels.

Context

Today, hydrogen is a promising energy carrier in a context of sustainable development. It begins to be used as energy storage for photovoltaic energy, as fuel for forklifts, light vehicles and locomotives, as heating energy... But the development of a market for hydrogen energy involves the deployment of the infrastructure for the production, storage, transport and distribution of hydrogen. The subject of this thesis consists in the design of the hydrogen supply chain, from production to distribution. It will be part of a multi-objective optimization approach. Indeed, in a sustainable context, it is essential to measure the impact of the global chain on the environment. But also, to ensure the full development of the hydrogen option, it is important to control the costs of the global supply chain, in order to propose a competitive price compared to other energy sources.

Objectives/ Expected contributions

The design of this supply chain is relatively complex. Indeed, hydrogen can be produced from diverse primary energy sources, such as hydrocarbons, wind, biomass, water, or solar energy...The hydrogen can be transported in gas or liquid form at different pressures, which requires pressurizing and liquefaction units. Then, to ensure good service quality, it is necessary to locate storage and distribution units as near as possible from customers.

So, the hydrogen supply chain (HSC) is a network of integrated facilities, i.e. nodes which are mutually connected and which interact in a specific way. These nodes include: (1) source of energy, (2) production technologies, (3) storage facilities, (4) transportation modes, and (5) dispensing (fuelling) stations.

To design such a network, there are many design and operational decisions to make. These ones include: (1) the number, location, size, and capacity of hydrogen production and storage
facilities, (2) the necessary transportation links for establishing the network, (3) the flow rates of hydrogen and energy sources, and (4) the production rates and the average inventory of materials. Moreover, a further difficulty of this work is to locate and quantify customer demand. Indeed, as the hydrogen sector is booming, it is impossible to rely on past data which cannot be collected. It is therefore essential to make predictions in the form of different deployment scenarios.

The model of HSC based on mixed integer linear programming involves a multi-criteria approach where at least three objectives have to be optimized simultaneously, i.e. the cost, the service quality and the environmental impact. Solutions to be searched will consist in a Pareto front, corresponding to various design strategies in the associated variable space. Multiple choices decision making analysis will be then selected to find the best compromise.

This work will be particularly valued by projects with territories wishing to develop the use of renewable energies.

**Skills and job profile**

A solid foundation in algorithms and combinatorial optimization are needed. Serious programming skills thus are essential. In particular, good practice of object-oriented language like C++ would be much appreciated, as well as a strong background in logistics.

**Keywords:**

Supply chain, hydrogen, multi-objective optimization, multi-criteria decision.

**References**

