Research Grants for PhD students from China Scholarship Council

Production Inventory Routing Problem in the Hydrogen Supply Chain

Supervisor's names : Dr Marie-Ange Manier (HDR) marie-ange.manier@utbm.fr
Dr Hervé Manier herve.manier@utbm.fr

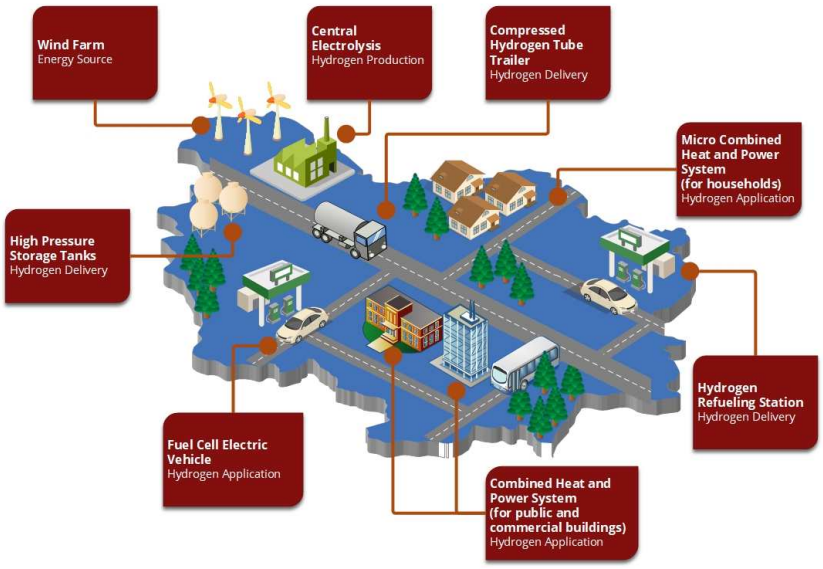
Research Team: Institut FEMTO-ST, CNRS, DISC/OMNI team
University : UTBM (Université de Technologie de Belfort-Montbéliard)

Research environment:

In the axis Transport and Mobility of the OMNI team, the proposed topic fits into the Logistics field. 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.



Then in recent years, the supply chain (SC) has been gaining increasing attention. The stakeholders are competing under globalized market. The consumers become more demanding on the quality, safety, traceability and transparency. Meanwhile, the researchers and practitioners are dedicated in reducing the total chain cost as well as providing customers with good service. In order to meet the need of today's high competitive markets, decision makers are focusing on integrating different activities within the Supply Chain so as to benefit from the coordination of those activities. Examples of partially integrated planning include the Production Distribution problem with direct shipment (PD) ([5]) and the Vendor Managed Inventory (VMI), arising the Production Distribution Problem (PDP) ([3]) and the Inventory Routing Problem (IRP). These two patterns have been widely studied and large amount of cost savings have been obtained. To go one step further, one may expect to benefit more from a fully integrated policy, which involves the Production Inventory Routing Problem (PIRP) ([1], [2]). PIRP is an integrated operational planning problem that jointly optimizes production, inventory and routing decisions simultaneously.

Objectives/ Expected contributions

We consider the Production Inventory Routing Problem (PIRP) in the application context of the

hydrogen supply chain. Many studies about PIRP deal with perishable foods ([4], [8], [9]), which involves constraints on the storage times and then which sometimes implies shortages in spite of a rather continuous production process.

In our case, the hydrogen production cannot be seen as perishable, but other kinds of constraints must be considered which also imply such shortages. Indeed, in order to produce the cleanest hydrogen possible, renewable resources are used. But one of the problems with the use of these renewable energies is that not only production is not constant, but also and above all it can be zero, like in the case of wind energy when the wind is not blowing. On the other hand, during these periods, demand does not stop. So we have to find a way to continue to supply the demand for hydrogen. One solution could be to have over-capacity production plants to produce more during those periods when "clean" hydrogen is in shortage, which would result in additional investment costs that would have a significant impact on the cost at the pump. Another scenario would be to store throughout the year to compensate for production declines. In addition, the demand for hydrogen is of two types. The first type is associated with infrastructures using hydrogen as a heating source, for example, or with vehicle fleets. These needs can be known in advance and then it is possible to forecast their supply. The second type of demand is associated with the development of hydrogen vehicles. This demand is not only much more difficult to quantify, but also its evolution is more difficult to predict. In fact, there are still very few vehicles running on hydrogen, and one could wonder if hydrogen will really be the energy of the future. The transport of raw materials for production of hydrogen to supply consumption points is also a crucial issue.

As we saw earlier, the connections to be made and the quantities to be transported are changing rapidly. It is therefore essential to be able to adapt while controlling costs and environmental impact. As we have just seen, the hydrogen supply chain is in constant evolution, and it is important to find an optimal solution to the Production Inventory Routing Problem that keeps the cost at the pump and the impact on the environment low. This is the overall objective of this thesis topic, which is clearly set in a sustainable context, and which follows on from previous work that we have conducted on the design of the hydrogen supply chain ([6], [7]). This work could be potentially valued by projects with territories wishing to develop their use of renewable energies and make optimal gain.

Skills and job profile

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

Keywords:

Production inventory routing problem, supply chain, hydrogen, operations research, multi-objective optimization

References

[1] Adulyasak, Y., Cordeau, J. F., & Jans, R. (2015). The production routing problem: A review of formulations and solution algorithms. *Computers & Operations Research*, 55, 141-152.

[2] Bard, J. F., & Nananukul, N. (2010). A branch-and-price algorithm for an integrated production and inventory routing problem. *Computers & Operations Research*, 37(12), 2202-2217.

[3] Boudia, M., & Prins, C. (2009). A memetic algorithm with dynamic population management for an integrated production–distribution problem. *European Journal of Operational Research*, 195(3), 703-715.

[4] Coelho, L. C., & Laporte, G. (2014). Optimal joint replenishment, delivery and inventory management policies for perishable products. *Computers & Operations Research*, 47, 42-52.

[5] Díaz-Madroñero, M., Peidro, D., & Mula, J. (2015). A review of tactical optimization models for integrated production and transport routing planning decisions. *Computers & Industrial Engineering*, 88, 518-535.

[6] Li, L., Manier H., and Manier M.-A. (2019), Hydrogen supply chain network design: An optimization-oriented review, *Renewable & Sustainable Energy Reviews*, Vol.103, pp.342-360. https://doi.org/10.1016/j.rser.2018.12.060

[7] Li L., Manier H., and Manier M.-A. (2020), Integrated optimization model for hydrogen supply chain network design and hydrogen fueling station planning, *Computers & Chemical Engineering*, 134(4), pp.342-360, https://doi.org/10.1016/j.compchemeng.2019.106683

[8] Yantong, L. I., Feng, C., Zhen, Y., & Calvo, R. W. (2016). A Production Inventory Routing Planning for Perishable Food with Quality Consideration. *IFAC-PapersOnLine*, 49(3), 407-412.

[9] Yantong, L. I., Feng, C., Zhen, Y. (2017). Coordinated Production Inventory Routing Planning for Perishable Food. *IFAC-PapersOnLine*, 50(1), 4246-4251.