Sustainable Disruption Management

The world we live in is globalized. Goods are seldom made in the place where they are used or consumed, and we do increasingly travel to other countries for either business or pleasure. In our everyday lives we rely on well-functioning global transportation systems to continue the standard of living we are enjoying. We rely on airlines being able to transport us safely and efficiently around the globe and may all recall when the Icelandic volcano with the difficult name, Eyjafjallajökull, disrupted our ability of doing so.

The backbone of world trade, shipping, does not reach the news in the same way, when operation is disrupted. Never the less, we may recall that the Suez Canal was closed due to riots in Egypt, that the fuel price was impacted by threats of closing of the Strait of Hormuz, and we do from time to time hear about acts of piracy outside the coast of Somalia.

All of these events lead to very severe disruptions to transportation systems. Less severe disruptions do, however, also have a significant impact on transportation systems and on most days, an airline or a shipping company will experience some level of disruption. Most often due to weather, but other issues, such as e.g. technical problems or congestions are also typical causes of delays. Returning a transportation system to its original plan of operation is referred to as Disruption Management.

Disruptions are, however, not the only cause of concern to the transportation industry. Fuel is becoming an increasingly expensive resource, and it is being consumed in vast amounts by the transportation industry. The single largest expense for both airlines and shipping companies is fuel, which exceeds both labour costs and capital expenditure.

This thesis addresses how fuel considerations can be taken into account when managing recovery from disruptions. The underlying work of this thesis is carried out as an industrial PhD project in co-operation with the company Jeppesen, which have the airline industry as its primary area of business and the maritime industry as its secondary area. For this reason the thesis has been divided accordingly, with the primary focus being on the airline industry and the secondary being on the maritime industry - more specifically, the liner shipping industry, which in terms of network structure has many similarities with airline networks.

The thesis presents how disruption management fits in to the larger scope of optimization related processes in an airline and provides a brief survey of these. The thesis goes into more detail with disruption management and does as its main contribution describe how this can be combined with flight planning. Flight planning is the calculation of the horizontal and vertical flight path, which an aircraft should follow in order to get from airport A to airport B. The objective of this calculation is typically to minimize fuel consumption, while satisfying airspace regulations. To the knowledge of the author the work in this thesis represents the first papers combining disruption management and flight planning through an integrated optimization approach.

An additional contribution of the thesis is to show how flexible flight speeds can be used to improve recovery from disruptions, while at the same time allowing an airline to trade off fuel costs with passenger delay costs. Experimental results show both large cost savings of 5.7% and very large reductions in passenger misconnections of 66% by applying the approach.

This contribution is carried over to the liner shipping industry, which despite being a different industry and having different constraints than the airlines, has sufficient similarities in network structure to benefit from a similar recovery concept. This work has lead to a successful development of an optimization model for the Vessel Schedule Recovery problem (VSRP), which is an area that has not previously been addressed in published literature. Experiments show up to 58% savings in recovery costs compared to manually realized recovery costs for real-life cases.

The thesis does furthermore describe the airspace structure and how flight planning is carried out within the constraints of this structure. In both the US and Europe the flow of flights between different regions is centrally managed in order to reduce the negative impact of airspace congestions. A final contribution of the thesis is an approach and a model, which combines disruption management with flexible flight trajectories. In a situation, where a specific area of the airspace is congested, this approach can help an airline with a more proactive handling of the kind of disruptions, which are caused by congested airspace. This is again an area, which has not previously been addressed through an approach combining flight planning and disruption management. The real-world results show considerable yearly savings of above 5.1 million USD for a medium size airline operating in European airspace, which is significantly affected by airspace congestions.