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# A large neighborhood search based matheuristic for the tourist cruises itinerary planning

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ABSTRACT

The planning of itineraries for tourist cruises is a complex process where several features, such as vessel selection, port services, and requirements for point of interest to be inserted in each tour, must be addressed. The present work models the tour planning problem as a variant of vehicle routing problem considering specific constraints such as: fixed number of tours, not mandatory visits of all nodes, multiple time windows, possibility to choose among different travel speed values. The resulting mathematical formulation lead to a complex model for which commercial solvers fail to solve large instances in a reasonable time. To overcome this issue we propose a Large Neighborhood Search based matheuristic, in which an over-constrained version of the mathematical model is used to exhaustively and efficiently explore large neighborhoods. Test results performed on a real case instances demonstrate effectiveness of the proposed approach.

## 1. Introduction and literature review

The business of tourist cruises itineraries requires companies to create different and appealing cruise tours with a convenient mix of visited locations in suitable time constraints and a balance of costs. Several decision parameters affect the design of itineraries (Barron & Greenwood, 2006). As stated in Asic and Lukovic (2016), the selection of attractive destinations is a crucial process for a cruise company, but it has received a limited attention in the literature. One of the first attempts to address optimal cruise itineraries design has been reported in Leong and Ladany (2001), where a mathematical model for cruises calls selection is proposed. Hersh and Ladany (1989) formulate an optimization model for routing and scheduling vessels, given the set of ports to visit. This model has been applied to real data related to cruises starting from Florida and visiting Jamaica, Puerto Rico and Bahamas, while an application to coastal cruises in China has been discussed in Yang, Gao, and Li (2016). Another crucial issue is the control of travel speed to reduce fuel consumption. The largest part of vehicle routing problems assume fixed speed along arcs, but, reducing cruise speed, when it is not necessary to maintain the maximum speed to respect time constraints, yield to a significant cost reduction (Psaraftis & Kontovas, 2014). Several applications in maritime logistics and ship routing consider speed as a decision variable. Speed reduction could have not only an impact from the economic point of view, but also from the environmental one, as pointed out in Wen, Pacino, Kontovas, and Psaraftis (2017) and Fagerholt, Gauser, Rakke, and Psaraftis (2015). Tramp ship routing and scheduling optimization with variable speed has been addressed in Norstad, Fagerholt, and Laporte (2011) and Wen, Ropke, Petersen, Larsen, and Madsen (2016). The impact of carbon emissions taxation on ship travel speed decision has been analyzed in Wang and Xu (2015). Speed optimization has been also considered in some green logistic applications, in which the objective is to reduce pollution, such as the Pollution Routing Problem (PRP), introduced by Bektas and Laporte (2011) and its time dependent version presented in Franceschetti et al. (2017). Although speed optimization has become a hot topic in the last years for freight transportation, to our knowledge, no application has been presented on passengers transportation.

Several researches analyzed the network design of liner services, mostly applied in the shipment industry. In the present work we formulate the problem as a variant of vehicle routing with profits for an application to the tourism industry. Moreover, we compare in a real case application the performance of the exact approach with a Large Neighborhood Search (LNS) based Matheuristics (MH) which exploits some peculiarities of the formulation. Literature addressed the solution approach in different ways, considering that the operation of liner services is a complex activity, requiring several interconnected design and planning decisions that may be coupled in several ways. Some researchers investigated design, planning and operation of linear services both in commercial and in tourism industry. Liner services are well described in Giachetti, Damodaran, Mestry, and Prada (2013) where

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cruise liner can be deployed for different tours having different lengths with re-positioning operations and crew scheduling to be solved on several class of job operators. The crew scheduling problem is formulated as an extensive Mixed Integer Linear Problem (MILP). Real case test instances can be solved by a commercial solver and test results highlight the decision support capability of MILP models. The service network design is investigated by Huang, Hu, and Yang (2015). Differently by our work, where cruise liners are analyzed, Huang et al. (2015) propose an optimization model for containerized shipment with the aim to minimize empty container re-positioning. The developed model is tested on realistic instances composed by 22 ports which can be managed by commercial solvers. In Gelareh and Pisinger (2011), the design of deep sea liner shipping is considered. This problem can be configured as a design of hub and spoke network for ocean container shipping. In these settings the resulting MILP model is challenging even for small instances. Thus, a decomposition approach is taken. Reinhardt and Pisinger (2012) solve the liner shipping design network with an exact approach based on branch and cut. The described liner design network problem is similar to Vehicle Routing Problem with Time Windows (WRPTW) with several specific features such as "butterfly" routes and transshipment which are exploited in the cut generation. A metaheuristic approach is proposed by Brouer, Desaulniers, and Pisinger (2014) for the same problem defined as Liner Service Network Design Problem (LSNDP). Differently from standard VRP problems LSNDP are characterized by not fixed sources and destinations and can be multicommodity. Brouer et al. (2014) propose a model based metaheuristics where a mixed integer program is solved to identify insertions and removals of port calls from a single service and mathematical programming is indeed inserted into a Large Neighborhood Search based metaheuristics. In this work we will follow a similar approach. Matheuristics are often used in Vehicle Routing based problems as pointed out by the survey of Archetti and Speranza (2014) where matheuristics are defined as approaches where mathematical programming models are used in a heuristic framework. The authors classify the matheuristics approaches in: (*i*) *decomposition approaches*, where some or all of the subproblems are solved using mathematical programming models; (*ii*) *improvement heuristics*, where mathematical programming models are used to improve a solution found by a different heuristics approach; (*iii*) *Branch-and-price/column generation-based approaches*, where the exact method is modified to speed up the convergence.

The analysis demonstrates the application of liner network design to cruise industry is only partially covered by research literature. As noticed by Rodrigue and Notteboom (2013), in cruise industry is critical to have a proper strategy oriented to itineraries and not destinations. In our paper we present a real problem where liner network design is applied to cruise industry. While the formulated model shares some similarities with the related shipping industry, several specific features are considered bringing in evidence the important of itinerary planning.

## 2. The liner network design problem in the cruise industry

The problem hereafter presented has been specified in a case study related to a company operating cruises in the Mediterranean sea. The planning of itineraries for cruise companies is a critical tactical decisional problem affecting resource usage and company's capacity to generate revenue in the medium period. In order to support this decisional process, several types of information must be taken into account, in particular, port attractiveness, variable and fixed costs, availability of resources and its compatibility with ports. The addressed problem is treated as a total cost minimization even if several interactions with marketing and revenue management functions are needed to finalize the planning decision. The problem consists in defining the composition of cruises offered by a cruise company to customers that are valid for a medium period (for example: a season). The output of the planning problem is an itinerary for each of the company's vessel which must be repeated in all the planning horizon (e.g. the season) and such that a linear combination of fixed and variable costs are minimized. Fixed costs mainly consist of fares payed to ports while variable costs mainly consist of fuel consumption. The itineraries are deployed in a specific region (e.g. the Mediterranean sea) and the solution of the planning problem define the subset of the region's ports where the cruises are deployed. In particular, a subset of the ports represented in the test instances are depicted in Fig. 1. The cruise company is interested in

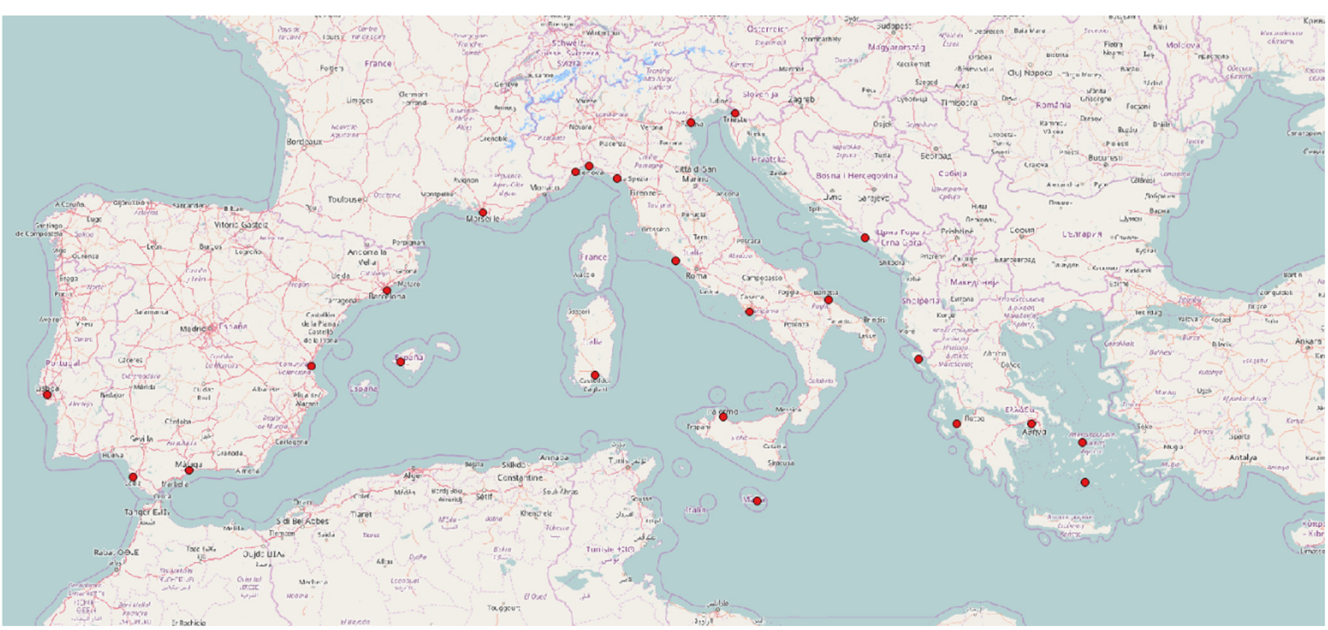

**Fig. 1.** Map of available ports.