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Cruise service planning considering berth availability and decreasing marginal profit

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ABSTRACT

This paper addresses a decision problem on planning cruise services for a cruise ship so as to maximize the total profit during a planning horizon. The service is a sequence of ports (harbor cities) that the cruise ship visits. In this decision problem, the constraint about the availability of berths at each port is taken into account. In reality, if a cruise service is executed by the ship repeatedly for several times, the profit earned by the cruise service in each time decreases gradually. This effect of decreasing marginal profit is also considered in this study. We propose a nonlinear integer programming model to cater to the concavity of the function for the profit of operating a cruise service repeatedly. To solve the nonlinear model, two linearization methods are developed, one of which takes advantage of the concavity for a tailored linearization. Some properties of the problem are also investigated and proved by using the dynamic programming (DP) and two commonly used heuristics. In particular, we prove that if there is only one candidate cruise service, a greedy algorithm can derive the optimal solution. Numerical experiments are conducted to validate the effectiveness of the proposed models and the efficiency of the proposed linearization methods. In case some parameters needed by the model are estimated inexactly, the proposed decision model demonstrates its robustness and can still obtain a near-optimal plan, which is verified by experiments based on extensive real cases.

1. Introduction

Over the past two decades, the cruising industry has developed dramatically. In 2014, there are 296 cruise ships in the world (Cruise Ship Statistics, 2015). With such a massive fleet, the global cruise industry generated revenues of 37.1 billion U.S. dollars, and the number of cruise passengers in the worldwide level reached a total of 22.04 million in 2014 (Cruise Ship Statistics, 2015). Those 22.04 million cruise passengers were mainly from developed countries: Among them, 12.16 million (55%) were from North America, 6.39 million (29%) were from Europe and 3.49 million (16%) were from the rest of the world. However, as the cruising industry is an oligopolistic industry, the majority of the huge cruise market is shared by three cruise companies, which are Carnival, Royal Caribbean, and Norwegian Cruise Lines with market shares of 41.8%, 21.8%, and 8.2%, respectively (Cruise Industry, 2015).

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For those cruise companies, a few strategic or tactical decisions have a long-lasting effect on the profitability of their cruise ships (Veronneau and Roy, 2009). This is due to the fact that the cruising market fluctuates significantly by the regional and seasonal differentiations: Some cruise ships are routinely repositioned from the Caribbean to Alaska in summer, or from the Mediterranean to the Caribbean in winter in order to appeal to more cruise passengers. Recently, a number of mass market cruise ships were relocated to the Asia to gain profit from the fast-growing Asian market. When a cruise ship is relocated to a new region for the sake of seasonal variations or market repositioning, a home port will be selected at first. Then, various loop candidate cruise services are designed for the cruise ship to operate: a candidate cruise service operated by the cruise ship is a cruise route, in which the ship picks up cruise passengers at the home port, visits the ports of call covered in the route, and returns to the home port where the passengers get off the ship.

In the cruising industry, service planning is often independent among different cruise ships, and planning problems of different cruise ships can be solved individually. According to Rodrigue and Notteboom (2013), the cruise ship deployment focuses on a specific cruise ship rather than a fleet of cruise ships. Cruise ships are often unique, even if the cruise ships have the same capacity (in passengers), different cruise ships have significantly different onboard activities, which are part of cruising experience. The same cruise route traversed by two cruise ships construct two different cruise services, as the onboard activities are different. Our research is applicable to this situation. If two ships are very similar and serve the same region and visit common ports of call, then the competition between the services provided by the ships have to be accounted for.

This study assumes that when a cruise ship is repositioned to a new region, a home port and a set of candidate cruise services are chosen in advance, and addresses the Cruise Service Planning (CSP) problem. This problem aims to determine how to plan cruise services for the cruise ship to operate in the region for a period of time. In other words, over the period of time, how to choose cruise services from the candidate cruise services for the cruise ship to operate in order to maximize total profit. However, the solution for the problem is not as straightforward as it seems. In a cruise service, there are several ports of call for the cruise ship to visit. Therefore, the berth availability of the ports of call should be considered when operating a cruise service. For instance, Wusong Kou terminal is a cruise terminal in Shanghai (China) with two available berths. Based on the arrival schedule of the terminal for the incoming cruise ships in Year 2016, on a specific day, there might be two cruise ships scheduled to moor at the terminal. If the cruise service operated by the cruise ship also arrives at the terminal on that day on schedule, the cruise service is unable to be operated due to the lack of berth.

Determining whether or not to choose a cruise service for the cruise ship is based on the scheduled rotation time of the service and the marginal profit of operating the service (i.e., the operating profit). Empirically, operating a cruise service with a high daily operating profit (i.e., the operating profit divided by the service's rotation time) is more likely to cater to the preference of the cruise ship. Whereas, a preferable cruise service might not be always profitable in a planning horizon: the marginal profit of operating a cruise service is not constant in the real situation. If a cruise service is repeated several times, its marginal profit decreases gradually. This phenomenon attributes to that few potential cruise passengers would order a cruise service if the cruise service has been repeated many times. Therefore, the effect of the decreasing marginal profit should also be considered in the CSP problem.

Based on the above analysis, this paper presents an explorative study on the CSP problem considering berth availability and decreasing marginal profit, in which optimal services for a cruise ship to operate are to be determined. In our study, firstly we build an integer linear model assuming that the marginal profit of operating a cruise service is constant. Then, an integer nonlinear model is formulated for a general problem, and two methods are proposed to linearize the model. One of the two methods takes advantage of the concavity for a tailored linearization, and the model linearized by this method is more efficient to be solved based on computational results. Some properties of the problem are also investigated and proved. By using DP, we investigate the NP-hardness of the problem under different cases. By analyzing some commonly used heuristics, we prove some useful theorems, for example, we prove that if there is only one candidate cruise service, a greedy algorithm can derive the optimal solution. The effectiveness of the proposed models is verified by extensive numerical experiments. Lastly, based on extensive real cases, robustness tests are conducted to show that in case some parameters needed by the model are estimated inexactly, the proposed decision model has its robustness and can still obtain a near-optimal plan.

The remainder of this paper is organized as follows. Section 2 reviews the related works. Section 3 presents a brief problem description and proposes the mathematical models. Complexity analysis and extensive comparison with heuristics are conducted in Section 4. The results of numerical experiments are reported in Section 5. Conclusions are then outlined in the last section.

2. Literature review

The cruise shipping related studies could belong to the area of tourism research as cruise ships provide cruise passengers with tourism service. Meanwhile, it can be also sorted into the area of maritime research as the cruise services are akin to container liner services. However, the past research on cruise shipping is limited, the reason of which may include: (i) the worldwide cruise ship tourism just accounts for about 2% of the world tourism market revenue, thus the tourism related researchers have not paid much attention to the cruise shipping related studies (Gui and Russo, 2011); (ii) the maritime logistic related researchers mainly focus on the freight transportation (e.g., Bell et al., 2011; Meng and Wang, 2012; Song et al., 2015).