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Optimization-based decision support system for crew scheduling in the cruise industry ☆

Ronald E. Giachetti [a,*], Purush Damodaran [b], Sid Mestry [c], Claudia Prada [c]

[a] Department of Systems Engineering, Naval Postgraduate School, Monterey, CA 93943, USA
[b] Department of Industrial and Systems Engineering, Northern Illinois University, Dekalb, IL 60115, USA
[c] Department of Industrial and Systems Engineering, Florida International University, Miami, FL 33174, USA

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ABSTRACT

Crew members on cruise ships are hired in a global labor market, and a major cost for cruise lines is moving crew members from their home cities to the cruise ship's departure port. Complicating the crew scheduling problem is the uncertainty due to no-shows, terminations, and other reasons for crew to terminate their contract prematurely. To address this problem, this paper describes a scheduling system that implements a two-stage planning process that first determines overbooking levels for the number of crew to offer contracts to, and then second, a goal integer programming formulation to minimize the movement cost of assigning crew to ships while maintaining adequate crew levels and a desired crew region composition. We solve actual-sized problems characteristic of the cruise industry in a reasonably short amount of time. Experiments comparing the actual crew movement costs to the system's projected crew movement costs show that the scheduling system can consistently reduce the movement costs in the range of 9–23%, better maintain desired crew levels, and better maintain desired crew region composition.

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1. Introduction

As a service industry, cruise lines rely on having a large, well-trained crew to not only operate their ships, but also to provide the high level of guest services for which the cruise line industry is known. A single cruise ship can have between 1000 and 1500 crew members, and the largest cruise ship, operated by Royal Caribbean Cruise Lines, has 2500 crew members. In 2010, Carnival Cruise Lines, the largest cruise line, operated 93 ships with 65,000 crew. Collectively, the US based cruise industry has 167 ships and employs more than 250,000 crew members on board those ships (Anonymous, 2010).

The crew are hired internationally with large recruitment centers found in the Philippines, India, Caribbean, and Eastern Europe. In addition to their salary, the cruise line pays to feed and house crew members, as well as all the expenses incurred by crew to sign on the cruise and to sign off the cruise. The latter cost, called the movement cost, is for the crew member to travel from a gateway city near their home to the departure port of the ship they are assigned to. The movement cost includes airfare, exit and entry visas, hotel, meals, and the local travel expenses incurred by the crew member to join the ship and to return home after their tour. Moving crew from their homes to the cruise port of call (and the return) is a significant cost in the cruise industry – one major cruise company makes almost 150,000 crew movements in a year and spends approximately $90 million annually just on crew movement costs. Even small percentage reductions in crew movement costs can result in substantial cost savings.

Of the many costs associated with crew, only the crew movement costs are affected by the many operational decisions involved in crew scheduling. The reason is that within a given job category, for the most part, all crew members earn the same salary and are paid the same benefits. The only cost that depends upon the crew schedule is the movement costs. There can be significant differences in airfare costs, visa processing costs, and other travel-related costs depending on where the crew member is recruited from, the port he moves to in order to join the ship, and when he is scheduled to join and depart the ship.

In this paper, we describe an optimization-based decision support system called LAPS[1] to schedule crew so as to minimize the total cost of crew movements for the entire fleet of ships operated by a cruise line. The decision problem of scheduling crew is complex due to the many inter-related decisions, the size of the problem, and the need to maintain the high levels of service demanded in the cruise industry. The crew schedule must obey many internal business policies, international regulations, and national-level regulations

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* Corresponding author. Tel.: +1 831 656 2670.
E-mail address: regiache@nps.edu (R.E. Giachetti).

[1] LAPS evokes the idea that crew do "laps" on a ship.

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depending on where the cruise ship visits. We first describe the overall system architecture and how the system is partitioned into a demand planning module and a crew scheduling optimization module. The demand planning problem is to determine how many crew members are needed on a ship. It must consider the uncertain behavior of crew members who do not show up for their assignments or who terminate their contracts early. Once demand is estimated, then crew can be scheduled to ships and itineraries. The crew scheduling problem is formulated as a goal and integer programming problem to minimize the movement cost while satisfying each ship's demand as well as many other constraints. We do a computational analysis and parametric analysis to explain how the system works, as well as analysis of scheduling individual ships versus multiple ships simultaneously. Our results demonstrate the cruise lines can cut crew movement costs significantly while maintaining their desired level of service quality.

Our primary contribution is specification of a crew scheduling system that can efficiently obtain optimal solutions for the problem sizes demanded by the cruise line. Moreover, the resulting crew schedules outperform manually generated schedules by reducing overall cost and better maintaining desired crew numbers on-board ships. The problem of crew movements in the cruise industry has not been addressed in the literature, and, in practice, none of the major cruise lines headquartered in Florida utilize any optimization in crew scheduling. This paper demonstrates a system that supports crew scheduling with optimization while maintain flexibility for human schedulers to manage the scheduling process.

The paper is organized as follows: Section 1.1 describes the operations of a cruise line and how it recruits and assigns crew to ships. Section 2 reviews the related literature on employee scheduling. Section 3 presents the crew scheduling systems and its underlying models. The system is partitioned into crew demand planning with a stochastic overbooking model and then crew scheduling with an integer programming model. Section 4 presents our computational analysis. Section 5 evaluates the model including comparisons between model performance and actual performance as experienced by the cruise lines. Section 6 summarizes the main contributions of the article and makes conclusions.

1.1. Cruise line operations

Cruise companies operate internationally with major cruising destinations in the Caribbean, Mediterranean, Alaska, and other locations. A typical cruise line has a fleet of ships serving these different destinations. The ships sail different length itineraries ranging from 3-night cruises to 1-month or even longer cruises. However, the most common cruise remains the 7-night Caribbean cruise. A cruise itinerary starts at what is called the departure port where all passengers and new crew members join the ship. The itinerary usually ends at the same port, the passengers and terminating crew disembark, and a new itinerary is started. A repositioning cruise is when a ship moves from one cruising destination to another destination. Common repositioning cruises are tied to the seasons such that ships move between Alaska and Mexico or Europe and the Caribbean as the seasons change from summer to winter.

On a single ship there are more than 100 different job classifications such as gallery steward, waiter, and commissary. Each job classification has a job description including the skills required to perform that job. Job classifications are defined such that all the crew within a job classification possess the same job experience and skills. So the cruise line is mostly indifferent with respect to scheduling one crew member over another to fill an open position for a particular job classification. The contract length for a crew member depends on the job classification. Contract lengths range from 6 to 10 months, with a mandatory 2-month vacation before the next contract begins.

In addition to the established crew, the cruise line is constantly recruiting and maintains what is called a gap pool, which is a list of new employees who are qualified and ready to start work. During scheduling, when there are no returning crew to fill a position, then the scheduler will draw from the gap pool. In some instances even the crew available in the gap pool are insufficient to meet the scheduling requirements so the recruiting agencies that are located world-wide are requested to find new hires to fill these positions.

Currently, cruise lines employ schedulers that are in charge of particular ships and job codes. The schedulers manually do the scheduling for each ship. The scheduling process is semi-automated with an enterprise resource planning (ERP) system to manage the transactions. While scheduling the crew, the scheduler needs to consider many performance measures and constraints. An important performance measure is the PAR level, which is the number of crew members needed on board for a particular job code. Additionally, the cruise line wishes to maintain a certain nationality mix of crew members on each ship and maintain sufficient crew members with various language abilities.

The PAR level is an important performance measure of the crew scheduling process because the PAR level is specified to maintain a desired level of service. The cruise industry is a service industry that relies on delivering a memorable, positive customer experience, and it views having adequate crew on board as essential to achieving this goal. Schedulers attempt to maintain the PAR level for each job code and ship they are responsible for. Maintaining the PAR level is difficult because of what are called the unplanned factors, which are unplanned crew movements that can cause the number of crew on board to vary. Unplanned factors include no-shows and early departures. No-shows occur when a crew member with a signed contract does not show up for their assignment. Some no-shows are due to events outside of the crew member's control such as delayed flights, visa processing delays, and missed connecting flights. Other times, the no-show is because the crew member changed their mind and did not notify the cruise line. The second cause of unplanned movements is crew members who depart before their contract end date due to factors including: compassionate leave, medical leave, resignation, or termination. We will treat no-shows and unplanned departures together, collectively called unplanned factors, because in either case, the result is the ship has fewer crew members on board than what was planned.

The crew costs involve three major costs: salaries, accommodations, and movements. Of these three cost components only the movement costs are subject to optimization. As previously mentioned, the salary is the same within a job code, and the accommodations provided to a crew member are also dictated by their job code. The largest component of movement costs, accounting for about 70%, is the airfare cost. Airfare costs vary according to the route flown, season, and other factors. Secondary to airfare is hotel and local travel costs, followed by visa costs. The LAPS crew scheduling system is designed to minimize the movement costs subject to the goals of maintaining PAR, meeting nationality mix constraints, and satisfying all business rules pertaining to crew schedules.

2. Review of related work

To our knowledge, there are no other papers that directly address crew scheduling for the cruise line industry. In fact, our work with the cruise lines indicates that optimization has not yet been used in this context. However, the crew scheduling problem described herein is a type of staff scheduling problem. Ernst, Jiang, Krishnamoorthy, and Sier (2004) review workforce rostering problems in general. Some staff scheduling problems are formulated as multi-period assignment problems in which people are assigned to jobs over time periods (Pentico, 2007). The crew scheduling prob-