Omega 40 (2012) 584–593

Contents lists available at SciVerse ScienceDirect

Omega

journal homepage: www.elsevier.com/locate/omega

Passenger and pilot risk minimization in offshore helicopter transportation

Fubin Qian [a,*], Irina Gribkovskaia [a], Gilbert Laporte [b], Øyvind Halskau sr. [a]

[a] Molde University College, Postboks 2110, N-6402 Molde, Norway

[b] Canada Research Chair in Distribution Management, HEC Montréal, 3000 chemin de la Côte-Sainte-Catherine, Montréal, Canada H3T 2A7

ARTICLE INFO

Article history:
Received 20 December 2010
Accepted 6 November 2011
This paper was processed by Associate Editor Yagiura.
Available online 22 November 2011

Keywords:
Helicopter transportation
Pickup and delivery routing problem
Risk minimization
Tabu search heuristic

ABSTRACT

In the offshore petroleum industry, employees are transported to and from the offshore installations by helicopter, which represents a major risk. This paper analyzes how to improve transportation safety by solving the helicopter routing problem with a risk objective expressed in terms of expected number of fatalities. A mathematical model is proposed and a tabu search heuristic is applied to this problem. Three routing policies are considered: a direct routing policy, a Hamiltonian routing policy, and a general routing policy. Extensive computational experiments are conducted on instances derived from real data in order to assess and compare these policies under a travel time, a passenger risk and a combined passenger and pilot risk objective. Several management insights can be derived from this study. In particular, our results show that passenger transportation risk can be reduced by increasing travel time at the expense of pilot risk. This can be achieved through a reduction of the average number of passengers onboard by applying either a Hamiltonian or a general routing policy. Our methodology can also be used to derive an equitable distribution of risk between passengers and pilots, considering that pilots fly much more frequently than passengers.

1. Introduction

Helicopter has been the main way of transporting personnel to and from offshore installations for more than 60 years. Kaiser [18] states that Humble Oil and Refining and Kerr-McGee began using helicopters to transport workers to offshore facilities as early as 1948. Travel by helicopter is more comfortable and less harmful in terms of travel sickness and tiredness as compared to travel by ship. However, helicopter transportation is perceived by many offshore workers to be an uncomfortable and risky part of their work. They experience heaviness and weightlessness during take-off and landing, heavy noise, strong vibrations, and even sometimes incidents or accidents. Vinnem et al. [32] claim that the hazards associated with helicopter transportation of personnel are among the main risks experienced by offshore employees. Table 1 presents a comparison of average passenger fatality rate per billion passenger-kilometers by transportation mode, in which the offshore helicopter transport holds the highest risk among all public transportation modes.

Helicopter accidents are frequently reported. For example, a fatal accident took place on April 1, 2009 when a helicopter carrying personnel from BP's Miller platform crashed into the North Sea, killing all 16 people onboard. European offshore helicopter data indicate that there have been 23 fatal and major injury accidents in the offshore oil industry from 1968 to 2000 [25]. A recent summary report from the Helicopter Safety Study 3 (HSS-3), undertaken by SINTEF Trondheim, shows that among 28 OGP[1] offshore accidents from 2000 to 2005, 22 occurred during the take-off or landing phase.

In helicopter transportation, a flight consists of a sequence of connecting stages that starts from an onshore heliport, visits some offshore installations to pick up or/and deliver some passengers, and usually ends at the same heliport. Helicopter routing can be viewed as a vehicle routing problem with pickups and deliveries (VRPPD). In this problem the aim is to design a set of minimum cost routes for several vehicles performing pickups and deliveries at customer locations, subject to capacity constraints and other side constraints [5,1].

Several studies on helicopter routing for passenger transportation have been published, with a focus on minimizing transportation cost in terms of travel distance or time [11,9,28–30]. Moreno et al. [24] and Menezes et al. [22] seek to minimize the flight costs, the number of flights, and the total number of offshore landings in order to improve flight safety. The objective function in the optimization model uses weights to balance these multiple goals.

Qian et al. [26] introduced a risk measure for passenger transportation by helicopter and proposed a risk objective in terms of the expected number of fatalities. They modeled the problem as an integer linear program which was solved by CPLEX

* Corresponding author. Tel.: +47 97435197; fax: +47 71214100.
E-mail addresses: qianfubin@hotmail.com (F. Qian), irina.gribkovskaia@himolde.no (I. Gribkovskaia), gilbert.laporte@cirrelt.ca (G. Laporte), oyvind.halskau@himolde.no (Ø. Halskau sr.).

[1] The International Association of Oil & Gas Producers.

0305-0483/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.omega.2011.11.003

for small instances. The purpose of this paper is to derive insights into passenger transportation safety by comparing the solutions obtained from optimizing risk or cost objectives under different helicopter routing policies. This study differs from traditional operational research studies because of its focus on learning as opposed to optimization [23] and on planning in a high risk environment (see, e.g., [27]). Our focus is therefore on analysis, as opposed to algorithmic design. Comparative analyses are performed on 120 instances derived from real-life settings through the application of a tabu search heuristic. We also carry out experiments in relation to the equity aspect of risk distribution between passengers and pilots.

The remainder of this paper is organized as follows. In Section 2, some routing policies and perspectives on reducing transportation risk are presented. A mathematical model to minimize the risk, together with a summary of the tabu search heuristic, are provided in Section 3. Computational results based on instances derived from a real-life setting are presented in Section 4, followed by conclusions in Section 5.

2. Passenger transport risk and routing policies

Risk is defined as the combination of the probability of an event (the equivalent term ‘accident frequency’ is used in the safety context) and its consequences (The International Organization for Standardization/the International Electrotechnical Commission Guide (ISO/IEC) 73). Using this definition, risk is often defined as an expected consequence; see Erkut and Verter [8] and Zografos and Androutsopoulos [33] who used this definition in the context of hazardous materials transportation.

Table 1
A comparison of average passenger fatality rates per billion passenger kilometers by transportation mode 1995–2004 (from UK Offshore Public Transport Helicopter Safety Record (1977–2006)) [31].

Transportation mode	1995–2004 average
Air	0.01
Rail	0.4
Car	2.8
Offshore helicopter	**6.3**

The risk for passenger transportation is defined as the expected number of fatalities for persons, which include both passengers and pilots. As in Qian et al. [26], risk is decomposed into take-off and landing risk (TL_{risk}) and cruise risk (C_{risk}):

$$Risk = TL_{risk} + C_{risk} = PTL \cdot f_{TL} \cdot p_{TL} + PFH \cdot f_C \cdot p_C, \quad (1)$$

where PTL is the total number of person take-offs and landings, f_{TL} is the probability of an accident during a combined take-off and landing operation, defined as the mean number of take-off and landing accidents per million pairs of take-offs and landings, p_{TL} is the probability of a fatal outcome for an individual person involved in a take-off and landing accident; PFH is the total person flight hours, f_C is the probability of an accident during one cruise hour, defined from statistics as the mean number of cruise accidents per million flight hours, p_C is the probability of a fatal outcome for an individual involved in a cruise accident. The PTL measure is a summation of persons exposed to pairs of take-offs and landings over all flight stages. The PFH measure is a summation over all flight stages of the number of persons on board, multiplied by the flight hours of each flight stage. Hokstad et al. [17] define the risk of offshore passenger transport as the product of accident frequency and the average consequence of an accident without classifying the risk into take-off and landing risk and cruise risk in helicopter transportation.

We implement and compare three routing policies: a direct routing policy (D), a Hamiltonian routing policy (H), and a general routing policy (G). Under the direct routing policy, each installation is served directly from the heliport so that the number of routes is equal to the number of installations. The term ‘Hamiltonian’ refers to the fact that each installation is visited exactly once for the combined pickup and delivery within a tour. In a general solution, each installation is allowed to be visited twice if necessary, once for delivery and once for pickup, and these visits to an installation may take place in two different flights.

Fig. 1 illustrates how risk for passengers and for pilots varies in five solutions under the three routing policies for a problem with two installations 1 and 2 to be served from heliport 0 by a helicopter with two pilots and transportation capacity for 19 passengers onboard. Suppose it takes 1 h to travel between the heliport and each installation, and 0.9 h between the two installations.

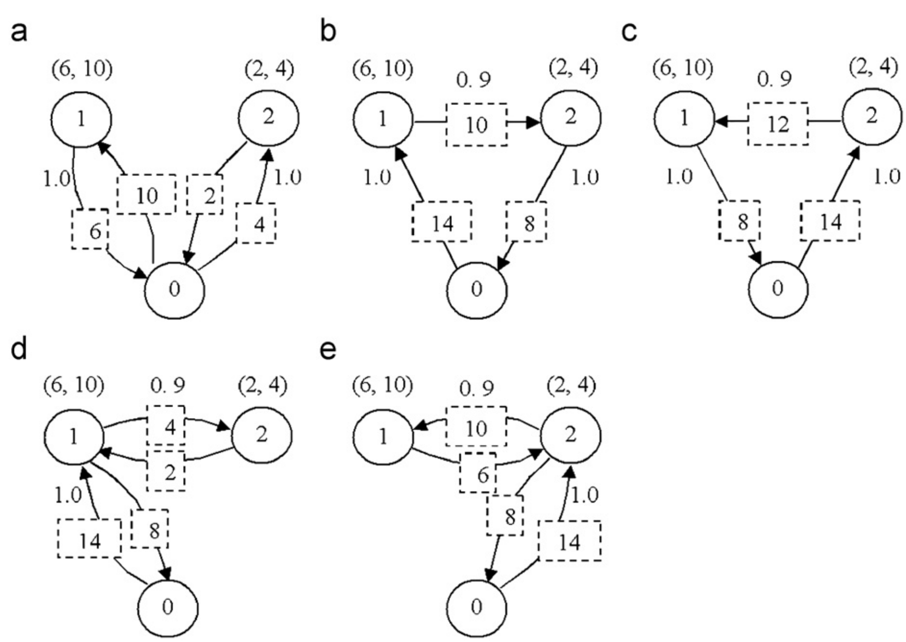

Fig. 1. Five possible solutions for the helicopter routing problem with two installations to be served.