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Combined emergency preparedness and operations for safe personnel transport to offshore locations ☆

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ABSTRACT

Long distances, sparse infrastructure, and adverse environmental conditions make the offshore emergency preparedness system in the High North a big and yet unsolved challenge. This applies in particular to the personnel transport between onshore bases and offshore facilities, which is usually conducted by helicopters. One of the issues to be solved is the sufficient coverage with emergency response units (RUs) in this sparse infrastructure environment. This paper proposes an answer to this issue by using sound logistical concepts, which involves connecting operations and preparedness. A mathematical model is introduced that combines a routing and a covering problem. On one hand, the shortest possible helicopter routes to offshore locations are sought, subject to being within the area covered by the deployed RUs. On the other hand, those RUs are placed so that a contingent helicopter ditching at any point on the chosen routes can be handled within given time limits. The combination of routing and covering forms a trade-off, which gives the decision maker the freedom to balance between the minimization of operational costs related to transport route distances and the long-term costs from response capacity requirements. A computational method that reduces the time to find a solution and allows decision makers to solve real life instances is presented. Computational experiments are conducted with the proposed model, based on prospective production sites in the Barents Sea.

1. Introduction

The Arctic region is estimated to contain 22% of the world's undiscovered oil and gas resources [22]. This makes the northern regions attractive for the petroleum industry, and is one of the reasons why activity at sea in the northern areas of Norway is expected to see an above average increase.

There are considerable gaps in today's emergency preparedness system of this region. A report by SARiNOR, a project to define future preparedness solutions in Northern Norway [9], points out that there is not enough private or public sector capacity to handle major accidents at sea that involve 20 or more persons in distress.

To get drilling licenses, operators have to show that they are able to operate safely, and in a self-reliant manner, i.e. they cannot rely on public preparedness services. Furthermore, their preparedness system should be able to handle even large scale incidents. To have offshore preparedness in place can be understood as a ticket-to-trade for anyone who wants to operate in this area, and to date, this ticket comes at a high price. This is why the petroleum industry has to find innovative solutions that ensure safety while keeping costs at an economically feasible level.

One of the major issues of future operations in this area is the safe transportation of personnel. In Norway, air transport by helicopter is the main mode to bring personnel to offshore installations and back. However, this mode represents one of the major hazards for offshore personnel [26]. In the UK, eight accidents in the past 30 years resulted in 110 fatalities [18]. Five accidents with 12 fatalities were recorded in Norway during the period of 1990–2009 [4].

Future offshore locations in the Arctic region may be located as far as 350 km or more from the shore. While this represents a big challenge for logistical operations in general, it is in particular posing a problem to the transportation of personnel to these offshore locations. In case a helicopter needs to make an emergency landing on water as shown in Fig. 1, which is commonly referred to as a *ditching*, measures have to be taken to be able to respond within a reasonable time. Thus, the transport routes need protection by rescue resources that are able to arrive at the scene quickly and can carry out the rescue within acceptable time limits.

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Fig. 1. A ditched helicopter near the Shetland Islands on 22 October 2012. *Source:* [1].

In this paper we propose to plan the offshore personnel transportation system and the offshore preparedness system in the Arctic region in a coordinated manner. By planning transportation routes near to each other, rescue units (RUs) could be located more efficiently as they would be able to cover more routes or bigger parts of the routes. In a sparse infrastructure environment, operations and preparedness could therefore be combined to make safe personnel transportation possible. We present a mathematical model which combines covering and routing decisions to consider these aspects. In practice, this can be used as a decision support tool that takes both strategic and tactical decisions into account.

Some aspects of the presented problem have been covered in the existing scientific literature. Rescue operation in the Barents Sea was studied by Jacobsen and Gudmestad [12]. They developed the subject of collaboration between RUs and proposed a rescue scheme for a long-range flight to a distant offshore location.

Research on covering models for facility location has a long history. Extensive reviews of this class of problems were presented by Farahani et al. [10] and, with a particular focus on emergency response, by Li et al. [14]. The latter highlighted the importance of the Emergency Medical Services Act of 1973, which defined a minimum response time requirement that has been the basis for most of the models studied afterwards. We take this one step further, as in the presented problem it is not sufficient to be on site within a defined timespan, but it is required to have the necessary capacity to rescue all *persons in sea* in time.

A better part of facility location and covering models related to the domain of offshore preparedness is dedicated to oil spill response. Verma et al. [23], for example, introduced a two-stage stochastic programming model with recourse for locating oil spill response facilities and deciding about what types of equipment to keep there.

Asiedu and Rempel [5] presented a coverage-based model for civilian Search-and-Rescue (SAR). Their multi-objective model aims to maximize coverage, minimize the number of RUs, and maximize the backup coverage of SAR incidents.

Akgün et al. [2] and Rennemo et al. [21] present models for facility location in emergency preparedness, taking into account distribution and routing. However, they mostly consider the disruption risk and the availability of infrastructure.

Covering models for facility location typically assume that coverage for a demand point is provided by a single facility. In our problem, several RUs are allowed to collaborate, that is, to conduct the operation together in order to rescue the *persons in sea* faster. In that respect this is a practical application of cooperative covering as introduced and studied by Berman et al. [6–8]. In this class of problems each facility sends a signal that decays over distance. The demand is covered if the aggregated signal exceeds a given threshold.

Berman et al. [6] provide cooperative versions of the classical location problems with a covering objective. Our problem differs from these in that we combine a cooperative cover location problem with a routing problem, with the objective to minimize the total route distance. While the demand points in the classical problems are given, the chosen routes determine the demand in our problem. Furthermore, our problem involves a set of different resources with varying properties.

Reducing the risk to personnel involves establishing measures to prevent accidents, as well as being prepared to act in the case of an incident. The operations research literature contains models related to helicopter routing that aim at reducing risk during operations. Menezes et al. [16] developed a helicopter routing model that improved travel safety by reducing the number of offshore landings and the flight time. Qian et al. [20] proposed a helicopter routing model with the objective to minimize the expected number of fatalities.

The rest of this paper is organized as follows: Section 2 describes the terminology used, including explanations of the response, its phases, and how our understanding of rescue capacity builds upon that. Section 3 presents a basic *combined routing and covering* model, as well as an extension for serving the installations on round trips. The real world application of the models is impractical, as the computational times are too long. Therefore, we develop a solution method that is described in Section 4. Section 5 presents a series of computational experiments, and our concluding remarks follow in Section 6.

2. Problem formulation

We consider the following problem: Personnel has to be transported to and from a number of offshore locations by helicopters. There are one or more onshore bases which can be used as points of departure. A full transport helicopter generally contains 2 pilots and up to 19 passengers.

In case of a helicopter ditching on the way, the crew and passengers may have to enter the sea. Due to the environmental conditions, particularly the low sea temperature, the human body can sustain this immersion only for a limited time. Dependent on the person's physiology, body protection equipment, and the sea state, this time limit may vary, but the Norwegian petroleum industry has adopted a requirement that a *person in sea* should be rescued within 120 min [17]. While this requirement is enforced only within a security zone of 500 m around an offshore facility, we follow the argument in [12] that the consequences for a *person in sea* do not depend on whether he or she is within or outside of this security zone. We therefore assume this limit to be valid for the whole route, starting from the onshore base to the offshore location. Measures have to be taken so that the whole crew can be rescued within this time limit in the case of a ditching.

Transports can be conducted on several routes at any time and in parallel, and all routes have to be covered by sufficient rescue capacity. It is, however, assumed that only one incident at a time can happen, which is a common assumption in risk analysis for the petroleum industry that is backed by its low accident rate [24].

For rescue operations, SAR helicopters and Emergency Rescue Vessels (ERVs) are used as RUs. An ERV does not carry out a rescue by itself, but is equipped with a Fast Rescue Daughter Craft (FRDC), which is launched from the ERV, proceeds to the incident site, and conducts the operation. Henceforth, the ERV/FRDC combination will solely be referred to as an ERV for the sake of convenience.

Each RU has specific performance characteristics that influence its rescue capability. The location of RUs can generally be freely decided, but some restrictions may apply. SAR helicopters are