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A temporal accessibility model for assessing the ability of search and rescue in Nansha Islands, South China Sea☆

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ABSTRACT

Time is an indispensable means in accessibility expression and also an important index of the search and rescue (SAR) ability to a country. In this paper, a method for forecasting the location and probability of patrol vessel which is responsible for SAR on the sea is presented; and a temporal accessibility model for assessing the SAR ability of countries around South China Sea in Nansha is structured. In this study, 19 islands and cays in Nansha Islands are selected as rescue targets; eight ports in four countries around South China Sea are selected as SAR bases; patrol vessels belong to coast guard or maritime agency of countries around South China Sea whose displacement is over 1000 tons are selected as principal searchers and rescuers. Based on the density of ships passing the area and the distance from ports of each homeland, the distributions of patrol vessel which belongs to four countries around South China Sea are obtained. The SAR time of China, Vietnam, Malaysia and Philippines in Nansha were calculated based on the proposed method. The results indicated that due to the number of big patrol vessels, China Coast Guard is able to get to Nansha in minimum time, only half an hour for SAR; Vietnam gets second, one and a half hours; Malaysia gets third, 4.6 h; Philippines costs almost 7 h at the bottom of the list, because of the distance and the number of vessels. Taking consideration of the scattered distribution of islands, rocky coral reefs, bad weather and complex marine conditions, it is a very difficult job for SAR vessels. So it is necessary to set up several sub centers and shelters on appropriate islands or atolls in Nansha. And more importantly, how to enhance connection and coordination among countries around South China Sea, build harmonious and smooth SAR mechanisms or channels for cooperation, and improve the ability for solving emergency accidents in Nansha and even the whole South China Sea.

1. Introduction

Time is a key factor in maritime search and rescue (SAR) and also an exact and clear measure, which can be used in calculating large scale data or getting small scale results. Moreover, time is an indispensable means in accessibility expression. Time distance between cities were defined as the indicator to describe the accessibility and the change of provincial capital cities in China under the National Trunk Highway System from 1990 to 2000 (Li and Shun, 2001). Calvin and Paul (2012) created a high-resolution spatio-temporal, GIS-based public transit network model to measure the accessibility, in the form of travel time, from origins to destinations by way of public transit. Sung (2012) used travel distance from users' homes to library as indicator to describe the accessibility. So it is feasible to describe the ability of SAR by temporal accessibility model.

Researches on predicting trajectory of floater based on ocean ambient information are hot topics in maritime SAR field. An operational SAR model was presented to forecast the trajectory of the search and rescue objects in the Norwegian Sea and the North Sea (Breivik and Allen, 2008, 2013). The structure and main functions of the salvage assistant system were constructed based on the analysis of the general course of salvage and can be used to forecast the trajectory of floater on sea (Wu et al., 2008). A model based on the law of physics which govern the motion of a floating body in a given wind and surface current field was presented for predicting boat drift for SAR missions (Ni et al., 2010). Moreover, researches on optimum placement of rescue resources and maritime rescue grade

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Table 1
Main islands and cays in Nansha Islands.

Name	Type	Area (m^2)
Taiping Dao	Island	422141.09
Zhongye Dao	Island	400880.08
Danwan Jiao	Artificial island	297967.45
Nanzi Dao	Island	180427.29
Xiyue Dao	Island	160354.45
Beizi Dao	Island	145421.72
Nanwei Dao	Island	144537.97
Hongxiu Dao	Island	76 483.09
Nanyao Dao	Island	63 803.23
Mahuan Dao	Island	54 799.68
Dunqian Shazhou	Island	41 929.74
Jinghong Dao	Island	30 235.57
Zhong Jiao	Cay	11 277.41
Anbo Shazhou	Cay	11 001.51
Bisheng Jiao	Cay	7 944.74
Feixin Dao	Cay	7 753.45
Ranqing Shazhou	Cay	7 489.53
Xi Jiao	Cay	3 926.61
Shuanghuang Shazhou	Cay	3 901.76

Table 2
Seaports around Nansha.

Name	Country	Type	Use	Bathymetry (m)
Guangzhou	China	Estuary	C	11.5
Sanya	China	Bay	M & C	7.5
Kaohsiung	China	Bay	M & C	16
Manila	Philippines	Bay	M & C	10.9
Cam Ranh Bay	Vietnam	Bay	M	16
Ho Chi Minh	Vietnam	Estuary	M & C	11.2
Kota Kinabalu	Malaysia	Bay	M & C	9.1
Kuching	Malaysia	Estuary	C	8.5

*C means Civil, M means Military.

are gradually increasing (Azofra et al., 2007; Li et al., 2010). Obviously, the above researches have two limitations: the first one is that they are more suitable for small scale, and the second one is that they do not take time as a factor into account. However, time is significant important for maritime SAR. The shorter time cost in SAR activities, the greater the chances of survival.

When sailing on the sea, the ships not only often encounter the terrible weather conditions such as typhoons and billows often happen, but also encounter some risky submarine topography such as reefs, or dangerous situation such as piracies. Under these bad conditions, ships have to send out SOS signals for rescue. Some adjacent ships or SAR organizations which receive SOS will send patrol ships or rescue vessels to accident water area. Under the organization and coordination in IMO (International Maritime Organization), neighboring countries can establish a uniform SAR mechanism to ensure the safety of navigation (IMO, 1999). In this paper, a temporal accessibility model based on SAR time is presented to describe the SAR ability of a country and assess the SAR ability of surrounding countries. This model can provide efficient and harmonious SAR mechanism.

Nansha Islands is located in the south of South China Sea, between 12°10′ – 3°25′N, 108°15′ – 119°00′E, ranges 970 km wide from south to north, 1200 km long from east to west, covers 820 000 km^2 sea area. The topography of the bottom in Nansha sea area is varied and complicated, which is located on the continental slope extended from the Sunda Shelf to the central basin of South China Sea. Mountains rising from bottom of the sea form the main body of Nansha Islands (Zhao, 1996). There are 55 drying coral reef, and 35 of them are always above the surface of the sea. The areas of the islands on reefs are so small that the largest one Taiping Dao's area is only 0.4 km^2. The depth of most sea area is over 1000 m and suitable for sailing, but the nearer the coral reefs are, the shallower the water is. The water depth in reefs area varies abruptly from over 1000 to several meters (Zhong et al., 1996). The tide in most of this sea area is irregular diurnal, except southwestern diurnal area. The average tidal range is 0.5–1 m, but in shallow area the range expands a lot, about 2 times to deep sea (Song et al., 1996). The

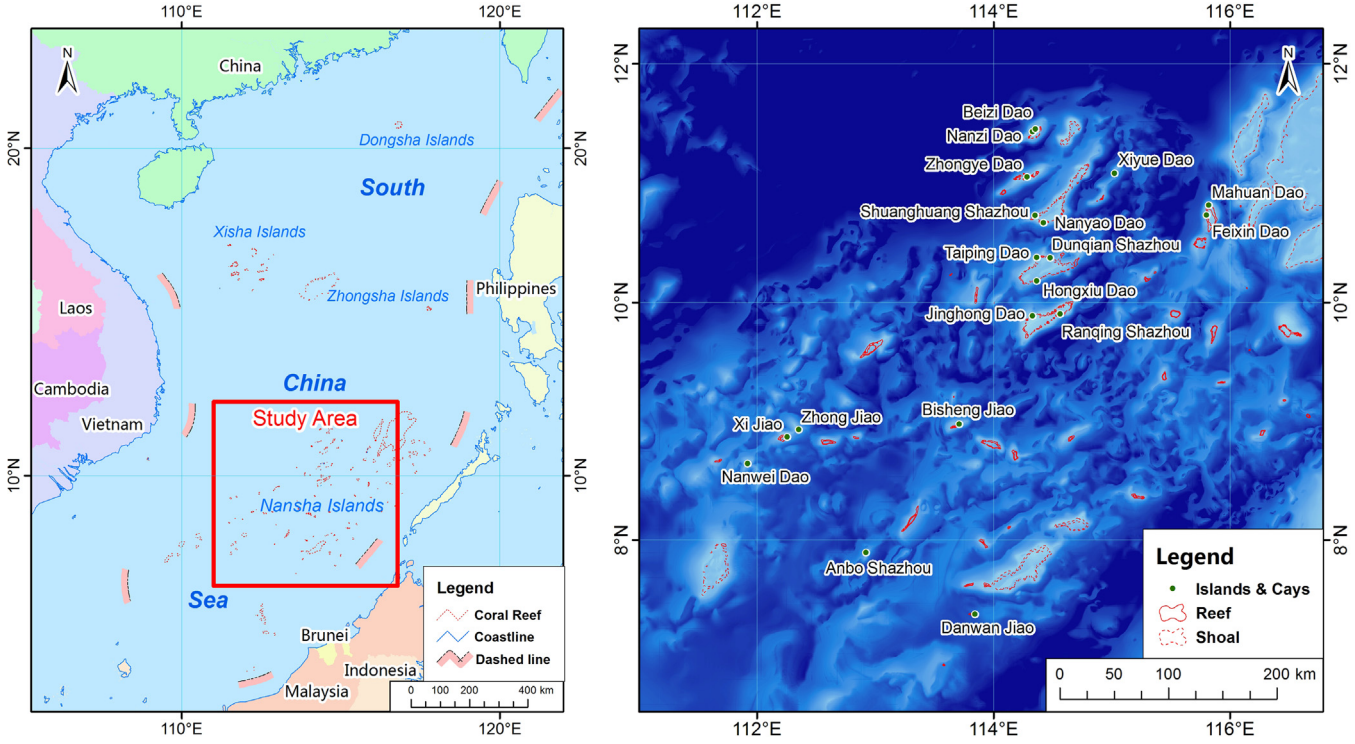

Fig. 1. Location of Nansha Islands and islands in study area.