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Analysis of Marine Conflicts

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ABSTRACT

The traffic conflict technique (TCT) is a powerful technique applied in road traffic safety assessment as a surrogate of the traditional accident data analysis. It has subdued the conceptual and implemental weaknesses of the accident statistics. Although this technique has been applied effectively in road traffic, it has not been practised well in marine traffic even though this traffic system has some distinct advantages in terms of having a monitoring system. This monitoring system can provide navigational information as well as other geometric information of the ships for a larger study area over a longer time period. However, for implementing the TCT in the marine traffic system, it should be examined critically to suit the complex nature of the traffic system. This paper examines the suitability of the TCT to be applied to marine traffic and proposes a framework for a follow up comprehensive conflict study.

INTRODUCTION

The traffic conflict technique (TCT) is a systematic method of analyzing the traffic maneuvers in order to evaluate and compensate any potential sources of safety hazards. This technique analyzes the operational and safety deficiencies by examining the critical vehicle interactions, symptoms of erratic driving, unsafe maneuvers or near-misses. Before the first formal proposal of this technique by McFarland et al. in 1954, traditionally the traffic safety researchers used the accident statistics as the basis of diagnosing operational and safety deficiencies. However, as more researchers examined the traffic safety issues, the weaknesses of the accident statistics as safety assessment criterion become apparent. In most cases, occurrence of accident is an outcome of a complex process of interaction involving the driver, the vehicle and the road environment. Hence, it is sometimes difficult to pinpoint the causes of accidents just from accident counts alone. Moreover, the frequency of accidents is segregated by locations, time and type resulting in low accident counts at individual sites which could be insufficient for a sound statistical analysis. Moreover, accident statistics are imprecise, inconsistently reported and not reliably collected which could give rise to biased conclusions. The researchers then considered the conflicts or near-misses as a surrogate of the accident statistics. The main advantage of using the conflicts is having a larger database within a shorter period of time compared to the accident statistics. It also solves the ethical problem of waiting for sufficiently larger number of accidents to take place first before taking any regulatory measures.

Increasing interest of the researchers in application of this technique has refined the concepts and implementation procedure through several conferences, congresses and workshops with publications amounting no fewer than a hundred. Some of them investigated the technique subjectively (Perkins et al., 1967; Campbell et al., 1970; Kruysse, 1991) whereas some treats it objectively (Allen et al., 1978; Balasha et al., 1980; Chin et al., 1997) in order to obtain sensibly good results. However, use of this technique in marine traffic safety assessment has not become popular so far, although it has some distinct advantages in the data collection and extraction process over the road traffic due to the presence of a real-time monitoring system.

This paper examines the suitability of the TCT for applying in the marine traffic system by identifying the inherent advantages of the marine traffic operation system over the road traffic. A framework for a follow up marine conflict study has been presented then by examining the difficulties associated with the application of this technique in order to obtain meaningful inferences from the analysis.

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RELEVANCE OF TCT TO MARINE TRAFFIC

It has been examined that the TCT is a useful tool for safety diagnosis of the road traffic interactions. In the process of implementing it efficiently and effectively, difficulties arisen regarding the data collection and analysis procedure. These difficulties sometimes restrict the use of this technique to some extent. However, these difficulties could easily be handled in order to use this technique effectively in marine traffic system, which in turn proves its suitability for this traffic system. These issues are elaborated in the following section.

Suitability of TCT to marine traffic

In order to examine the traffic interactions for safety studies, vehicle kinematic information is necessary for a quantitative analysis of the conflicts. Usually, in road traffic system, these data are gathered by recording vehicle movements for a certain time period using the time-lapse camera or the video technology. This method of recording vehicle movement paths has restricted the study area and the study time period to an extent. Moreover, the extraction procedure of the required information from the recorded media is time consuming and labor intensive. However, marine traffic has a great advantage over the road traffic in terms of the availability of vessel kinematic data due to the presence of a monitoring system.

The radar based Vessel Traffic Information System (VTIS) is the ship monitoring system, which provides real-time navigational information about the ships plying within the range of the system. In this integrated system, sensors from different locations track the vessel movements and output their signals to a central location where the operators monitor and manage vessel traffic movements. Due to the involvement of several sensors for a target ship the accuracy of these informations is quite good enough. This database can be a good source of vessel interaction data as well as the other geometric and operational data for a marine conflict analysis.

In road traffic system, the extracted vehicle kinematic data could be erroneous due to the manual extraction process from the recording media, whereas in the marine traffic system these data is accurate enough due to the involvement of several radar sensors. Moreover, it is hard to obtain the geometric data (e.g., length, width) of the vehicles from the recorded films. On the other hand, from the VTIS database it is possible to obtain these vessel geometric data (e.g., length, width, height, and draft) as well as the other possibly required information (e.g., ship tonnage, ship’s and pilot’s identity, speed, and direction of sailing etc.). These varieties of information could enable the TCT to pinpoint the main causes of shipping collisions effectively.

Due to the absence of such a monitoring system in the road traffic system, vehicle interactions can not be recorded over a larger study area for a longer time period. Therefore, the factors induced from the geometric and operational differences between different road sections as well as the time-dependent factors (e.g., seasonal variations, visibility) cannot be taken into account easily for a conflict study to make it generalized over the road sections and different time periods. However, in marine traffic system a comprehensive conflict study can be conducted considering all of these factors due to the presence of the VTIS, which can provide required data of a larger study area for a longer time period. Moreover, the variations in wind, current and tidal forces can also be taken into account for a longer study period. Hence, it can be concluded that availability of the monitoring system could make the implementation of this technique easier and more effective for the marine traffic system.

Furthermore, the vehicle movement process of the marine traffic is more complex than that of the road traffic. The former one is facilitated by the Navigational Assistance Service (NAS) provided by the VTIS, which enables the ship-crews to obtain real-time navigational advice from the port operators. Therefore, ship maneuvering process becomes a complex process of interaction involving the ship, her pilots and crews, the port operators and the marine environment. It is therefore not surprising that approximately 80% of the shipping accidents are caused by human errors in the design and operation stages (Soares et al., 2001). On the other hand, the road traffic is operated simply by the judgment of the drivers according to the surrounded road environment. Therefore, the marine traffic maneuvering process is more complex than that of the road traffic. Since the TCT has been proven effective in examining the causes of accidents for the complex road traffic interactions, it can be reasonable to use this technique to pinpoint the corresponding causes of the shipping collisions for the more complex marine traffic system instead of using the accident statistics alone.

Difficulties in applying TCT to marine traffic

Due to the presence of a monitoring system the marine traffic has some distinct advantages over the road traffic. However, there are some difficulties which could arise in the application of the TCT to the marine traffic.

The major shipping accident types constitute grounding, collision, foundering, and fire/explosion. Among these only the type ‘collision’ incorporates two or more ships in an accident event. The rest are caused mainly due to mechanical failure, fire or hitting objects other than a ship. Hence, the kinematic information may not be sufficient enough to pinpoint the causes of these accident types. The characteristics of the marine environment, the vessel system, and the attitude of the operators, crews and pilots may become important factors acting behind these accidents. Moreover, a collision between two ships may take place due to several reasons: insufficient or late reaction by the pilots and the port operators; poor visibility; insufficient space to maneuver; poor maneuverability of the ships; strong wind, current and tidal forces; meeting or crossing of ships at relatively narrow channels or at channel bends. Therefore, in order to use the TCT for diagnosing the safety deficiencies, the conflicts should reflect the whole range of the possible causes of these accident types.

Moreover, nearby the port areas usually a large number of ships remain anchored for loading/unloading purposes or simply for parking. These ships act as stationary objects in the collision process with another ship which is sailing. In such cases, the conflict event is actually single vessel interaction although the collision takes place between two ships.

Therefore, for the complex traffic interaction process involving the human factors as well as the vessel system and environmental factors it is necessary to examine the TCT critically before implementing it for safety assessment. A framework of a marine conflict study is discussed here which would be able to mitigate the difficulties associated with the implementation of this technique in marine environment.

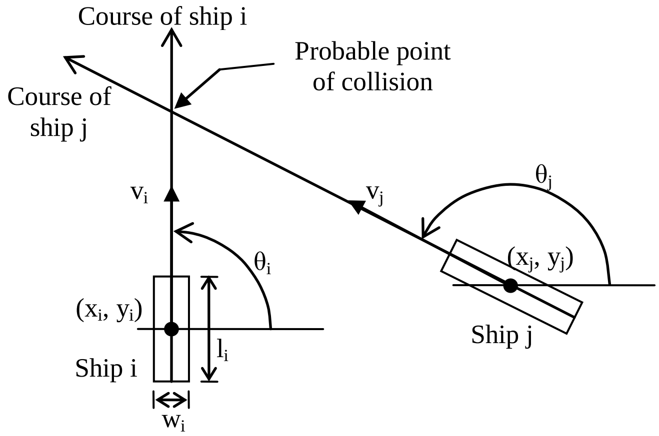

Fig. 1. A collision event between two ships

PROPOSED FRAMEWORK FOR A CONFLICT STUDY

In the proposed framework, the conflicts will be analyzed in such a way that they are objectively defined, quantitatively measured, and applied suitably. These are elaborated in the following sections.

Conflict definition

The conflicts should be defined in such a way that they can be evaluated quantitatively. Representing conflicts as 'nearness to collision' by using the time or space proximity between the involved ships is a good approach of defining it quantitatively. By considering the conflict event, as shown in Fig. 1, the conflict measure is a function of kinematic conditions and the ship attributes. This can be represented mathematically in the following way:

$$C_{i,j,t} = f\{ \underbrace{(x_i, y_i, x_j, y_j, v_i, v_j, \theta_i, \theta_j)_t}_{Kinematic\ data;\ changes\ with\ time},\ \underbrace{(l_i, w_i, l_j, w_j)}_{Ship\ Attributes;\ fixed\ with\ time} \} \tag{1}$$

where $C_{i,j,t}$ is the measure of conflict for ship i and j at time t; x_i, y_i, x_j, y_j are the corresponding positions of the ships at time t; v_i, v_j are the ship velocities at time t; θ_i, θ_j are the bearing angles of the ships at time t; and, l_i, w_i, l_j, w_j are the lengths and widths of the ships i and j respectively.

The most critical value of this measure (C_{cr}) will be obtained at the 'closest points of approach' of the ships. It is the minimum or the maximum value over time t for the ships i and j, based on the nature of the measure. Mathematically, it can be derived as follows:

$$\underset{i,j}{C_{cr}} = \underset{t}{Min}\{C_{i,j,t}\} \text{ or } \underset{t}{Max}\{C_{i,j,t}\};\ \forall_{i,j} \tag{2}$$

Moreover, the conflicts should be such defined that the definition reflects the intended purpose of the corresponding study. If the purpose is to diagnose the safety problems and establishing remedial measures for the problems involved, then it should be related to the common causes of the corresponding safety hazards. For example, if the study is intended to analyze the causes of shipping collisions, then the definition should be related the common causes of these collisions. On the other hand, if the purpose is to establish rules for a safe navigation clearance in the tailgating situations, then it should be defined in terms of relative time and space separations between the ships. It is therefore more appropriate to choose definitions that need not rely on the observed evasive actions taken by the pilots since a conflict situation may arise without showing any sign of evasive actions or these actions may not be easily observed. Moreover, the pilot's habit of taking evasive actions also varies from one to another. This process of defining conflicts can be able to pinpoint the main causes of the collisions. However, it would not be straight forward to identify the causes of the other accident types unless the conflicts can be defined in terms of the corresponding causes of these accidents.

Conflict measurement

The conflicts should be measured quantitatively according to the definitions rather than using any subjective scale of measurement. The subjective measurement procedure could produce biased results due to the judgmental error of different observers. For measuring the conflict measures quantitatively, the kinamtic information as well as the ship attributes is required. The VTIS can be a good source of such information.

By employing the quantitative measurements the stationary ships can be taken into account in the conflict process if they are considered as fixed objects, i.e., the situation is like that a moving ship is colliding on to a fixed object.

Suitable application

Besides being well defined and properly measured, the conflict measures must produce meaningful inferences from the analysis. In order to obtain such results, the conflicts should reflect correctly the corresponding causes of the examined safety hazards that are discussed earlier in the definition section.

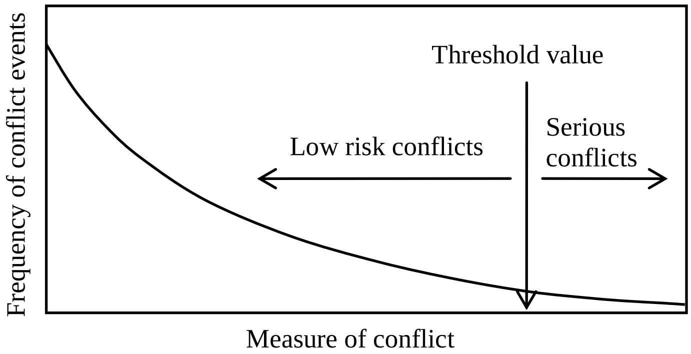

Fig. 2. Hypothesized frequency distribution of conflict events

For extracting meaningful inferences from the analysis, Chin et al. (1997) showed a comprehensive way of evaluating the serious conflicts by separating them from the other conflict observations. By employing a suitable threshold value of the corresponding conflict measure, the serious conflicts are distinguished from the non-serious ones, as shown in Fig. 2. From the probability function of the conflict measure the proportion of critical conflicts can be determined by evaluating the area under the curve beyond the threshold value.

CONCLUSION

The TCT is a powerful technique applied in the road traffic safety assessment as a surrogate of the traditional accident data analysis procedure. This technique is promising for the marine traffic safety analysis having some distinct advantages in the data collection and extraction process over the road traffic. It would be possible to extract meaningful inferences from the conflict analyses with the proposed framework where the conflicts are defined objectively, measured quantitatively and applied suitably. As a follow up to this the methodology will be applied to the existing maritime data for the Port of Singapore.

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