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**□** ARM **□** ENG **□** PAP **□** Input

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Agenda item [[2]](#footnote-2) 3.1

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Detection of near-miss risk and dynamic hotspot in near future

# Summary

Safety of navigation and prevention of the maritime incidents are very important goals of vessel traffic management supported by e-navigation tools and concepts.

The situations leading to the maritime incidents can be roughly classified into two: near-miss situation and dynamic hotspot situation, and the technologies to detect those situations in near future have been developed. Near-miss risk modelling developed by Fujitsu, based on the provided data set from MPA, enables quantification of ever-changing risk of collision in the Singapore Strait. It accurately quantifies the risk level synchronized with the typical VTS operations within Singapore Strait. It is also possible to predict the build-up of risk levels in particular contexts in the near future (risk-based dynamic hotspot), which could lead to better management of the vessel traffic.

These modelling and alert algorithms could form the suite of tools supporting the overall concept of e-navigation, for example, in the provision of collision avoidance advice to vessels for Maritime Service (MS) 2 – Navigational Assistance Service or recommending safe navigational routes for MS 3 – Traffic Organisation Service.

This paper introduces the technological description and the result of the experimental evaluation conducted within Singapore Strait.

## Purpose of the document

The Committee is invited to note the research work done by Fujitsu in collaboration with the Maritime and Port Authority of Singapore (MPA) on near-miss risk modelling in support of e-navigation and vessel traffic management.

# Background

1,642 major maritime incidents[[3]](#footnote-3) were reported in the world in 2014, and the cases resulting in not only the physical damage of vessels but loss of human lives and environmental pollution. The situations leading to the maritime incidents can be roughly classified into two:

* Near-miss situation that trajectories of two or three vessels come close and intersect each other to raise the collision probability
* Dynamic hotspot situation that vessels are populated densely enough to influence each other

Regarding the near-miss situation, the related two or three vessels can avoid it by recognizing the risk, having communication and taking an avoidance manoeuvre at appropriate timings. “Support for recognition and judgement of risk at timings appropriately before the near-miss” is the role for e-navigation, and quantifying the ever-changing risks is essential for that purpose.

In the dynamic risk hotspot situation, it is very difficult to mitigate the risk by individual decisions of captains or by the support from VTS once the hotspot is formulated as many vessels influence each other in the hotspot. “Predicting when and where the hotspots will be created” is the role that ICT should play, and indexing the risk and the possibility of formation of dynamic risk hotspot in near-future is the key requisite for that purpose.

# Discussion

## Methodology/Technology

### Near-miss risk detection - ensemble risk model

*Figure 3 - 1 Use of probability distribution of trajectory*



The technologies widely used in the industry is DCPA/TCPA but it does not well solve the trade-off problem that the false alert increases when lowering the threshold and that the failure in detection increases when raising the threshold. Contrary, developed ensemble risk model can accurately quantify the near-miss risk from comprehensive perspectives as it combines the risk calculation methods that quantify the subjective risk by captains and pilots (SJS: Subjective Judgement scales, SYSROC: Synthetically Subjective Risk Of Collision, CJ: Collision Judgement, and RiskLevel) to DCPA/TCPA. It is further improved with the below adjustment to have the calculated risk match with VTS officers’ sense and to minimize the false alarm and the failure in detection.

(Refer to Appendix 1-1 for other existing methods to calculate the near-miss risk.)

* Consideration of risk in case the path wavers by pre-calculating the possibility to change the path by vessel size and by speed (Figure 3-1)
* Adjustment of the risk index according to the situations (head-on, overtaking or crossing)

### Two types of dynamic hotspot

Dynamic hotspot that the collision risk rises at a certain time and place is different from the static hotspot that risk is always high in a certain place. Dynamic hotspot can be further separated into two types: risk-based hotspot and density-based hotspot. In this paper, detection and prediction of risk-based dynamic hotspot is discussed (Table 3-1).

(Refer to Appendix 1-2 for the definition of dynamic risk hotspot)

*Table 3 - 1 Two types of dynamic hotspot*



## Evaluation

### Evaluation process

To evaluate the technological accuracy and usefulness, we first extracted 23 near-miss cases and four hotspot cases from four-month historical data using the developed models, conducted experimental evaluation with MPA VTS officers, and set up the threshold to detect near-miss and hotspot ahead of time.

(Refer to Appendix 1-3 for the detail process of the experimental evaluation)

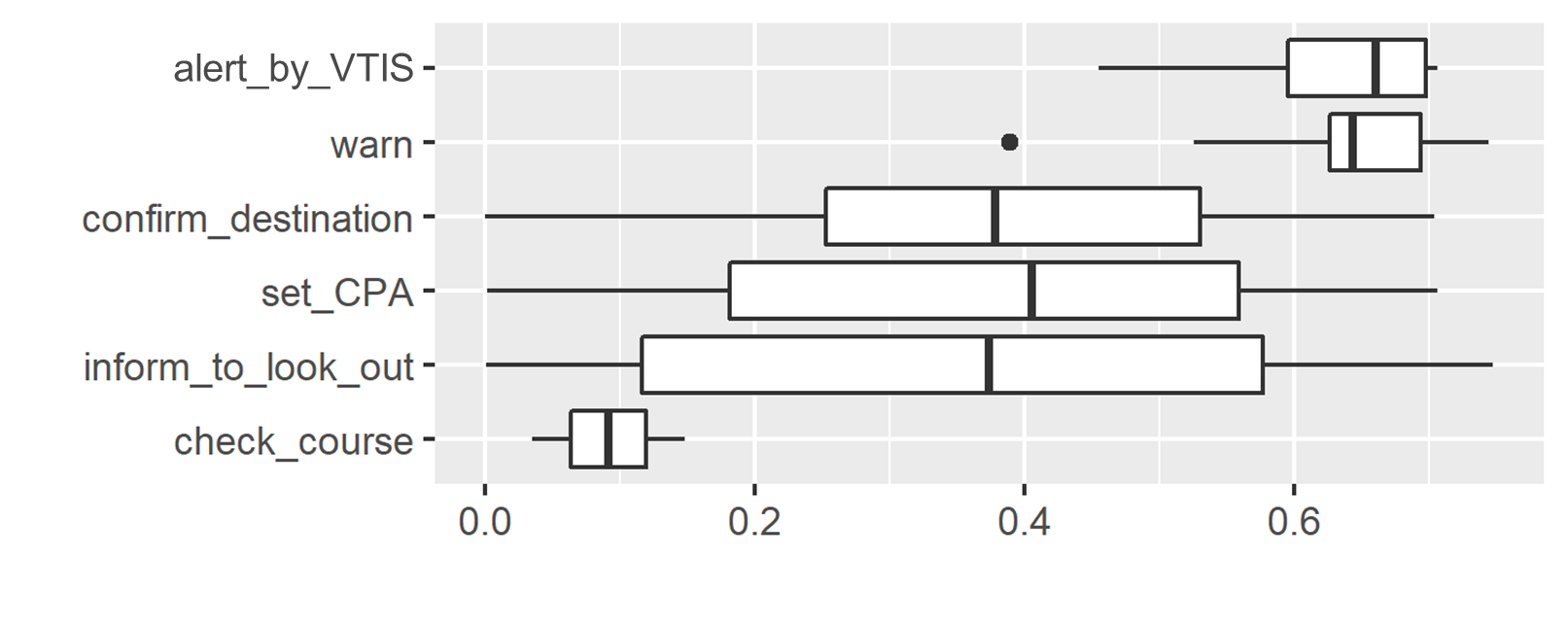
### Evaluation of near-miss risk detection

There are typically three steps in VTS officers’ actions: Information, Advice and Warning, and we have analysed the relationship of those actions and the corresponding risk level at each action timing (Table 3-2). Distribution of risk index by different VTS officers is shown in Figure 3-3. As indicated in the top two lines of the figure, risk indices at timings of alerts by VTIS and at timings of warning actions are roughly from 0.6 to 0.7, fitting in a narrow range.

On the other hand, risk indices at timings that officers confirm destination of vessels (confirm\_destination), at timings that officers check CPA on VTIS and enter into monitoring mode (set\_CPA) and at timings that officers prompt vessels to look out for other vessels (inform\_to\_look\_out) widely range from 0.1 to 0.6 with the median index value at 0.35 to 0.4. The reason for this variation may be that the actions such as Information and Advice are more dependent on individual skills because there is no alert by the system for those actions.

*Table 3 - 2 Three-step actions and corresponding risk index*

|  |  |  |  |
| --- | --- | --- | --- |
| Action step | Content | Time to near-miss | Risk index |
| Information | Provide information when detecting potential risk | 10 minutes | 0.35 |
| Advice | Give advice to manoeuver | 5 minutes | 0.6 |
| Warning | Warn potential collision | 3 minutes | 0.7 |



*Figure 3 - 3 Relationship between actions by POCC officers and risk index*

In the evaluation, we have confirmed that the technology stably detected near-miss risks for earlier actions (10 minutes for “Information,” and 5 minutes for “Advice”) while solving the trade-off problem that the false alert increases when lowering the threshold and that the failure in detection increases when raising the threshold. We have also confirmed that risk index information was useful to remind the situation when officers need to pay attention to multiple vessels or tasks simultaneously.

### Evaluation of dynamic hotspot forecasting

Figure 3-5 shows the traffic satiation a moment before the risk-based dynamic hotspot situation caused by two vessels crossing in between of a group of westbound vessels and a group of eastbound vessels.



*Figure 3 - 5 A moment before the dynamic risk hotspot generation*

Later, as shown in Figure 3-6, avoidance manoeuver occurred in a continuous way causing near-miss in this hotspot. The developed technology successfully detected the dynamic hotspot about 15 minutes before its generation, which will be useful for proactively overview the situation.



*Figure 3 - 6 Chain of avoidance manoeuver in dynamic risk hotspot*

Through the evaluation with VTS officers, it was confirmed that forecasting of risk-based dynamic hotspot would be very useful, especially for those who manage the overall traffic in longer time horizon.

## Implication for e-Navigation

The developed technologies will not only help enhancing the traffic management operations of VTS but also contribute to safe navigation of vessels and improvement of ship-ship and ship-shore communications. Specifically, the technologies will be relevant in providing related services in MS2 (Navigational Assistance Service) or MS3 (Traffic Organisation Service).

One of the challenges regarding the navigation in the congested water is that there are so many alerts from equipment on board of the vessels that it is sometimes counterproductive. By accurately quantifying the near-miss risk, it will be possible to prioritize the risks and limit the number of alerts. It will be also possible to conduct more strategic avoidance manoeuvring or adjust navigation plan based on dynamic hotspot information in 15 minutes.

Moreover, having the same risk information among vessels and VTS will help improving the quality of communication. Once the intuitive digital information of near-miss risks and hotspot information is shared among stakeholders, it can be expected that the burden on VHF communication to be freed and that VHF can be used more for its essential role to give last minute warning.

# Action requested of the Committee

The Committee is requested to note the research and development work done by Fujitsu on near-miss risk modelling in support of e-navigation and vessel traffic management.

MPA and Fujitsu welcome opportunities to collaborate to further the research and development work and enhance the developed models and algorithms.

1. Appendix to technology discussion
   1. Existing methods for quantifying near-miss risk

*Figure A1 - 1 The basic methods*



The basic methods for quantifying near-miss risk are based on:

* Distance between two vessels: Risk becomes higher when two vessels come closer (Figure A1-1 top)
* Crossing of extended vector: When paths of vessels in near future (extended vector) cross, the risk become high (Figure A1-1 middle).

A major method expanding from these basic methods is DCPA/TCPA (Figure A1-1 bottom), but it does not well solve the trade-off problem that the false alert increases when lowering the threshold and that the failure in detecting risks increases when raising the threshold because the method does not take situations that vessels are involved (head-on, overtaking or crossing).

One of the challenges regarding the navigation in the congested water is that there are so many alerts from equipment on board of the vessels that it is sometimes counterproductive. By accurately quantifying the near-miss risk, it will be possible to prioritize the risks and limit the number of alerts. It will be also possible to conduct

* 1. Definition of risk-based dynamic hotspot

We have defined risk-based dynamic hotspot as dynamic and complex situation with multiple vessels having higher collision probability, where avoidance manoeuver of one vessel has spill-over effect to others. In such situation, movements of vessels are extremely difficult to predict, and it is hard to resolve the situation by individual decision of vessels or by provision of information by VTS as many vessels are involved. Therefore, it is important to predict it before its occurrence.



*Figure A1 - 2 Spill-over effect of avoidance manoeuver in risk-based dynamic hotspot*

* 1. Experimental evaluation procedure

We have conducted the experimental evaluation in two rounds:

* Round 1
  + VTIS to play back cases extracted with the developed near-miss risk model
  + Officers to replicate usual operations on VTIS
  + Researchers to record timing and contents of every action of officers
* Round 2
  + VTIS and the developed tool to play back the same cases simultaneously
  + Officers to replicate usual operations mainly VTIS
  + Developed tool/researchers to provide additional information related to near-miss risk
  + Analyze the change in officers’ operation comparing with Round 1

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
2. Leave open if uncertain [↑](#footnote-ref-2)
3. Maritime Bureau, Ministry of Land, Infrastructure and Transport of Japan [↑](#footnote-ref-3)