# OPPORTUNITY FOR INCIDENT IN MARITIME SYSTEM: COUNTING PROCESS AND MODELING

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## Abstract

An accident can be considered as the culmination of a series of cascading events starting with a triggering incident. In maritime system, incidents are undesirable events related to control failures or system failures, such as navigation error, loss of steering wheel or loss of propulsion. These incidents can be summarized into vessel reliability failures or vessel operating errors. For an incident to occur there has to be an opportunity for an incident. This paper reports on the counting process that is modeled in a dynamic system simulation used in assessing risk of a maritime system.

Keyword: risk analysis, maritime system.

## 1. Introduction

The Washington State Ferries (WSF) is the largest ferry system in the United States. Ridership in 1998 for the ferries serving the Central Puget Sound region approximate 26.2 million persons, more passengers than Amtrak, the US passenger rail carrier, handles in a year [5]. Following the release of the movie *Titanic* and consequently a series of articles about the adequacy of lifeboats aboard the ferries, a risk assessment was undertaken at the request of the State Legislature [2]. One of the common goals of risk assessment in maritime system such as WSF system is to assess the adequacy of passenger and crew safety of the ferries in the system. Risk is often commonly described as a combination of the likelihood of an undesirable event

(accident) occuring and its consequences. An accident can be considered as the culmination of the of a series of cascading events starting with a triggering event [1]. Consequences, on the other hand, may include injury, loss life, or economic losses. For an accident to occur, there has to be an incident, and for an incident to occur, there has to be an opportunity for incident (OFI). For example, in a car collission with another vehicle, an incident could be a break failure and an opportunity for incident could be the situation when a car is on the road close to an on coming vehicle. When limited or no data is available, having the number of OFI's in a system would give an indication of the number of accidents that could have happened in the same time period.

In maritime system, incidents are undesirable events related to control failures or system failures, such as navigation error, loss of steering or loss of propulsion. These incidents can be summarized into vessel reliability failures or vessel operating errors. Whether an accident will occur is conditioned upon the occurences of an incident and the environmental, traffic, and other situational variables. If we are concerned with the safety of passenger and crew of the ferries, an opportunity for an incidence in this case will be the states of the system when the ferries are in the system either by themselves or when they are interacting with other vessels.

One of the models used to represent the maritime system is the dynamic system simulation. The simulation models actual system behavior as determined by historical data and established system procedures and as such is an appropriate modeling technique for identifying systemic interactions and for observing systemwide effects of interventions. An OFI then can be described as a situational descriptor of the system states and the attributes to the situational descriptor is in part dependent on the kind of interventions that is being modeled. A counting process can be built into the simulation to count how many times each opportunity for a vessel reliability failure or a vessel operational error will occur in a well-defined time period. The scope of this report, however, is limited to the counting process that is modeled in the simulation.

## 2. Counting Process of OFI's

As multiple ferries may be in the maritime system within one time period, or multiple vessels may be within the vicinity at one time, multiple OFI's may happen at the same time. Therefore, a counting process is needed to count the number of OFI's within that period. Often in modeling, one would like the model to represent the system as accurate as possible but at the same time one would like the model to be tractable. With this trade-off between tractability and accuracy of the model in mind, the counting process is modeled in the following manner. Consider the following situations (Fig. 1). In the first situation, the ferry is in the system by itself and one OFI (alone) will be counted. Suppose there are 4 attributes to the ferry then we would have 4 different combinations of OFI's.

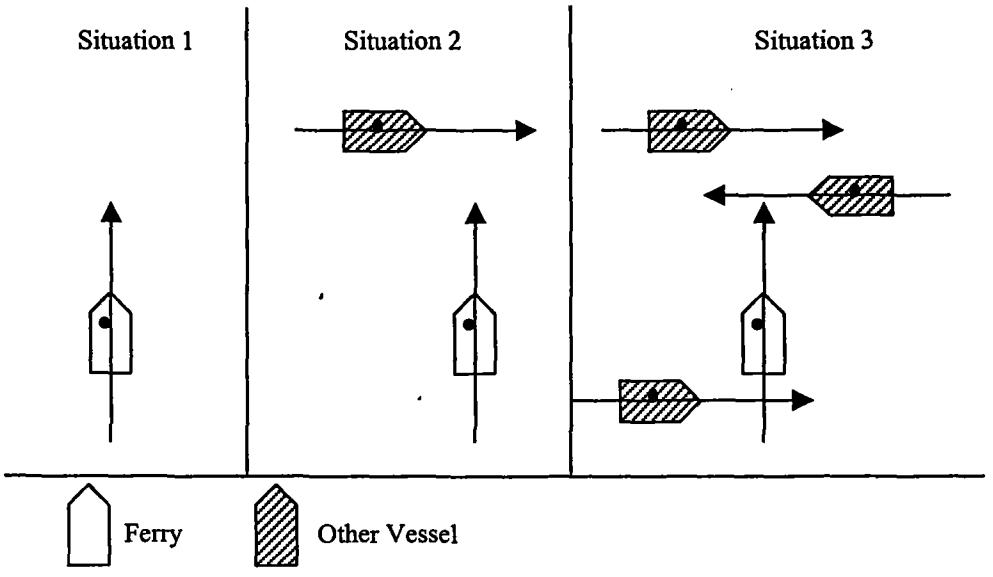



**Fig. 1** Situations in the Maritime System

In the second situation, when there is another interacting vessel in the system along with the ferry, one OFI (interaction) is counted. If there are four attributes to the ferry and three attributes to the vessels, then there are 12 possible combinations OFI's.

In situation 3, when there are three vessels interacting with the ferry, one possibility is to count the OFI as one. If there are four attributes to the ferry, three atributes to one vessel and four attributes each to the other two vessels, then we would have a total of 192 different possible combinations of OFI's. With this approach, if there are more than three vessels, the different possible combinations of OFI's would explode.

Another approach is to count one interaction with each vessel as one OFI, thus the number of OFI's for situation 3 would be counted as 3 instead of 1. This approach is equivalent to situation 4 (Fig. 2).

Situation 4

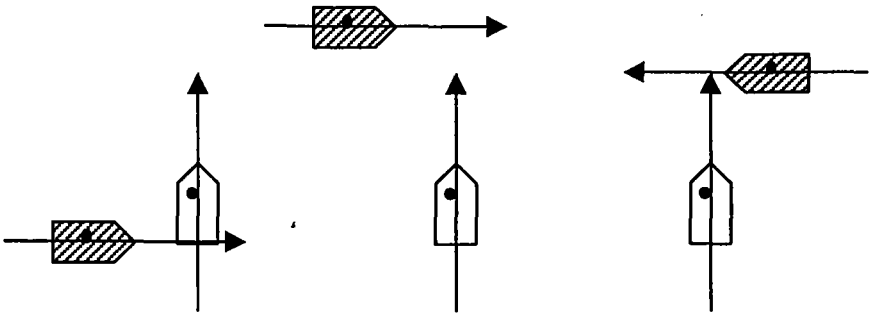


**Fig. 2** Situation 4 in Maritime System

The number of accidents in a given situation is given by

$$\text{No. accidents} = \Sigma \Pr(\text{Accident}|\text{OFI}) * \text{No. OFI's.}$$

As such, situation 4 is three times more dangerous as oppose to situation 3 when in fact it is reasonable to assume that situation 3 is at least as dangerous as situation 4. As a compromise between these two extreme approaches, we could further refine the OFI (interaction) in situation 4 by adding more attributes to the OFI's. It is assumed that when there are more than two vessels interacting, given that the ferry is interacting with a vessel, the occurences of an accident is only influenced by the direction and proximity of the other closest interacting vessel, where closest is defined as the other interacting vessels with minimum time to cross the ferry track. In doing so, the number of possible combinations of OFI's will not be as big as in situation 3 and at the same time the "dangerousness" of situation 3 can be adjusted for.

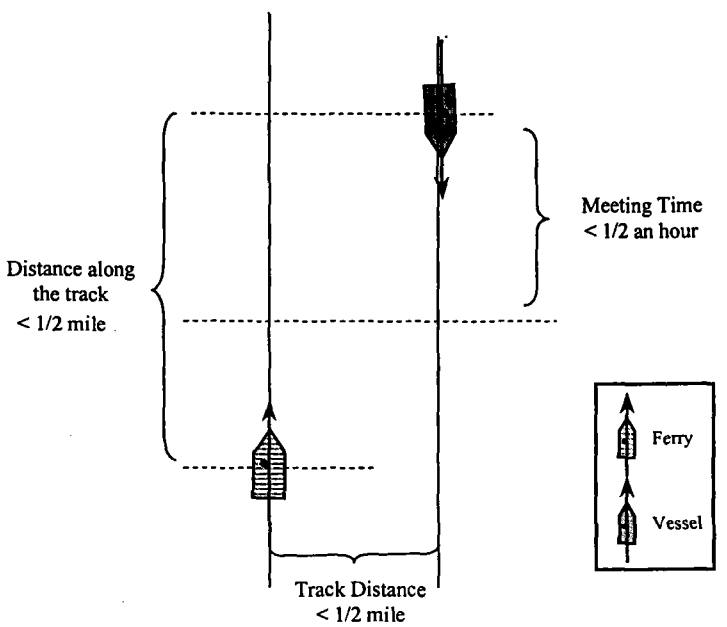
Before we could count the OFI's, we have to define what we mean by an OFI. For example in Air Aviation Risk Assessment, a natural way to define an OFI would be either a take off or a landing of an aircraft. In maritime system, however, there is no such natural candidate because of it's complexity. Below are the definitions of the OFI's that were used in the WSF risk

## 3. Definition of an OFI

There are many different kinds of accidents that can occur in the WSF system. For an example, an accident could be a collission, a grounding, an allision or fire/explosion. In the case of collision with another vessel, an OFI could be the interaction between the ferry and another vessel. For a grounding, a propulsion failure due to aging could have happened

(incident) which could lead to a grounding (accident). In this case then, the time that a ferry is in the system would be an OFI. In other cases, both the interaction and the time spent in the system would be an opportunity that could lead to an accident. With this in mind, the definition of an OFI in WSF system is summarized into four different models.

The first model deals with a vessel travelling on a track parallel to the ferry. It is judged that if a ferry is underway within a 2.5 minute period, a vessel that is travelling parallel within 1/2 a mile away from the ferry track would be an OFI (interaction) under the following conditions. If the vessel is travelling in opposite direction and the time it takes for the vessels to meet each other (meeting time) is less than 1/2 an hour or the distance between the ferry and the vessel along the ferry track (distance along the track) is less than 1/2 a mile, then it is a front interaction. If both are travelling in the same direction and the ferry is over taking the vessel and the time it takes to pass each other (passing time) is less than 1/2 an hour or the vertical distance between the vessels is less than 1/2 a mile, then it is a front interaction (Fig. 3a) On the other hand, if the vessel is overtaking the ferry, it is a back interaction (Fig. 3b).




FRONT INTERACTION

**Fig. 3a** Front Interaction

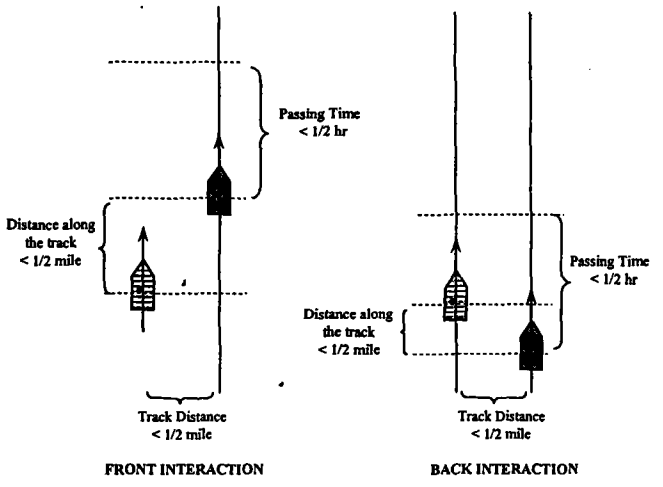



**Fig. 3b** Back Interaction

With this model, irrespective of the distance between the vessel and the ferry, the following cases will not be counted as interactions, i.e.,

(1) a vessel that has passed the ferry and travelling in opposite direction,

(2) a vessel with speed less than the speed of the ferry and travelling behind in the same direction and

(3) a vessel with speed greater than the speed of the ferry and travelling infront in the same direction (Fig. 4).

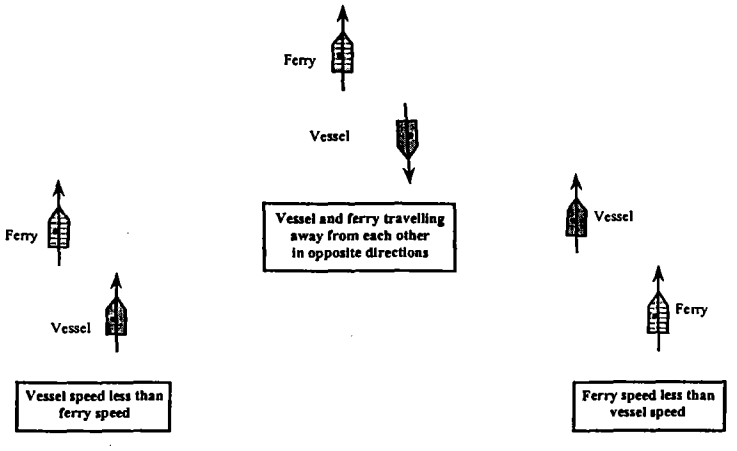
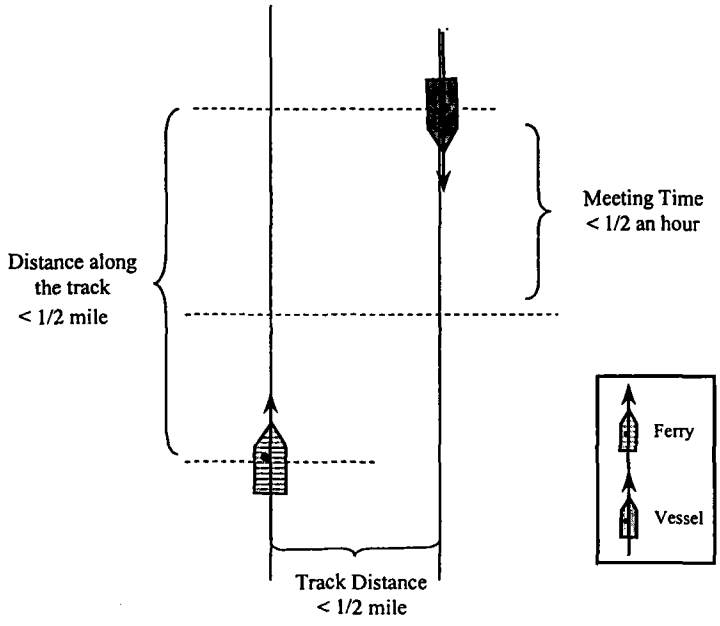



**Fig. 4** No Interaction

(incident) which could lead to a grounding (accident). In this case then, the time that a ferry is in the system would be an OFI. In other cases, both the interaction and the time spent in the system would be an opportunity that could lead to an accident. With this in mind, the definition of an OFI in WSF system is summarized into four different models.

The first model deals with a vessel travelling on a track parallel to the ferry. It is judged that if a ferry is underway within a 2.5 minute period, a vessel that is travelling parallel within 1/2 a mile away from the ferry track would be an OFI (interaction) under the following conditions. If the vessel is travelling in opposite direction and the time it takes for the vessels to meet each other (meeting time) is less than 1/2 an hour or the distance between the ferry and the vessel along the ferry track (distance along the track) is less than 1/2 a mile, then it is a front interaction. If both are travelling in the same direction and the ferry is over taking the vessel and the time it takes to pass each other (passing time) is less than 1/2 an hour or the vertical distance between the vessels is less than 1/2 a mile, then it is a front interaction (Fig. 3a) On the other hand, if the vessel is overtaking the ferry, it is a back interaction (Fig. 3b).




FRONT INTERACTION

**Fig. 3a** Front Interaction

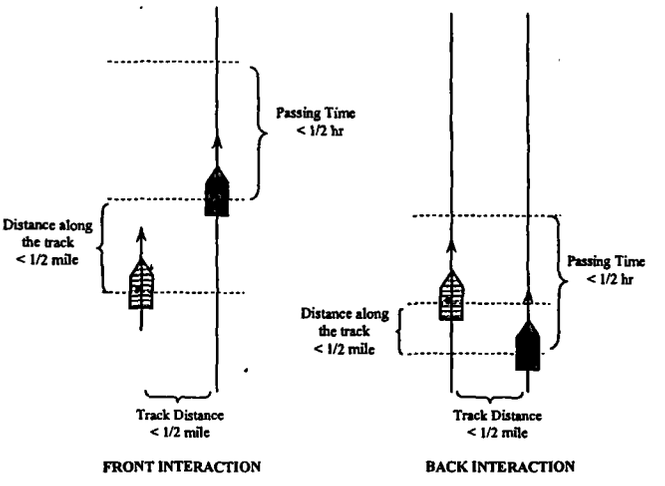



**Fig. 3b** Back Interaction

With this model, irrespective of the distance between the vessel and the ferry, the following cases will not be counted as interactions, i.e.,

(1) a vessel that has passed the ferry and travelling in opposite direction,
(2) a vessel with speed less than the speed of the ferry and travelling behind in the same direction and
(3) a vessel with speed greater than the speed of the ferry and travelling infront in the same direction (Fig. 4).

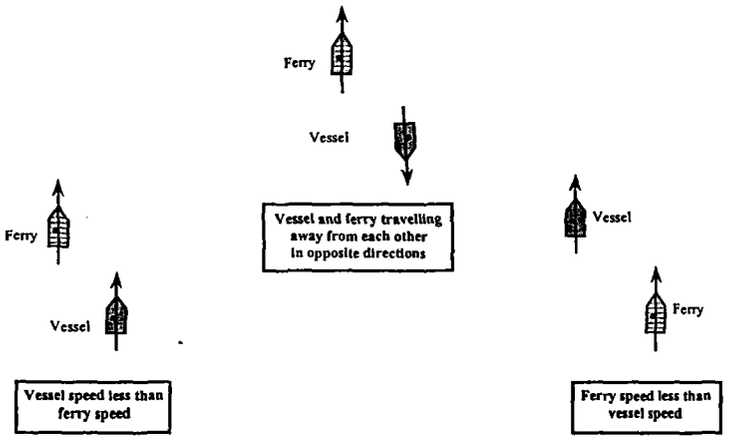



**Fig. 4** No Interaction

This model also assumes no distinction between vessel tracks that are within 1/2 a mile away from the ferry track. The closest other traffic will be based on the minimum passing/meeting time.

The second model deals with vessel tracks that are not parallel to the ferry track. It is judged that if a ferry is underway within a 2.5 minute period, a vessel that is not within a 1/2 mile away from the ferry but is within 1/2 an hour away from crossing the ferry track would be an OFI (interaction) under the following conditions. If the future position of the vessel when it crosses the ferry track is within one mile ahead of the future position of the ferry, then it is a front interaction. If it is within half a mile behind, then it is a back interaction (Fig. 5). Thus this definition only holds for vessels that have future crossing points. With this model, the closest other traffic will be based on the minimum crossing time.

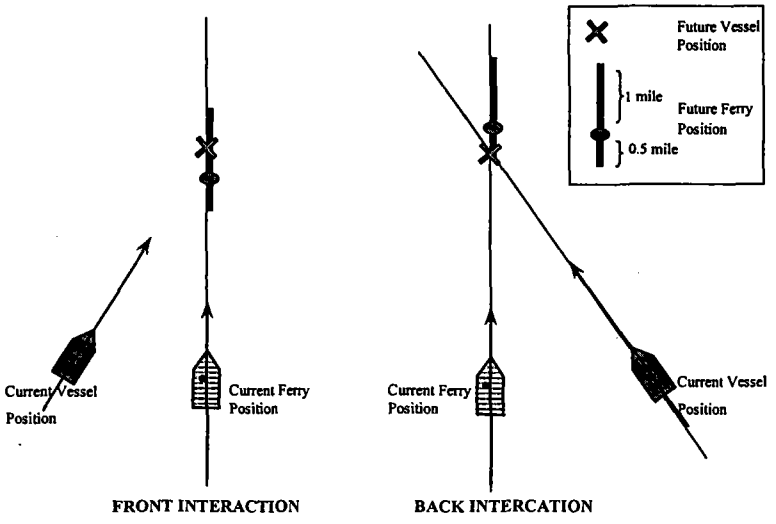



**Fig. 5** Front and Back Interaction For Non-Parallel Track

The third model deals with vessels that are within 1/2 a mile away from the ferry. It is judged that if a ferry is underway within a 2.5 minute period, any vessel within 1/2 a mile away from the ferry would be an OFI.

Let $\theta$ be the angle between the ferry track and the vessel track. For simplicity, if $-\theta_{FRONT} < \theta < \theta_{FRONT}$ then it is considered to be a passing situation, i.e., vessels are travelling in the same direction parallel to each other (Fig. 6).

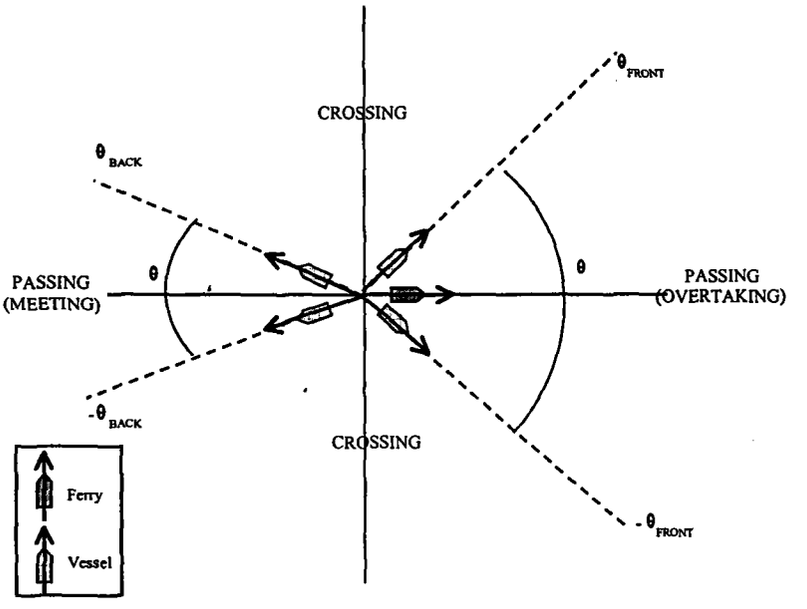



**Fig. 6** Passings and Crossings

Time to interaction will be time to passing if the vessels have not passed each other, otherwise it will be time that has elapsed since the vessels passed each other. This time to interaction is calculated using the component of the vector speed of the vessel that is parallel to the ferry track (Fig. 7).

The classification of the interaction into a front or a back interaction follows the same argument as in the first model by replacing the speed of the vessel with the component of the vector speed of the vessel that is parallel to the ferry track.

If $-\theta_{BACK} < \theta < \theta_{BACK}$, then it is considered to be a meeting situation, i.e., vessels are travelling in the opposite directions parallel to each other. In this case, the time to interaction will be the time to meeting if the vessels are approaching each other, otherwise it will be the time that has elapsed since the vessels approached each other. As in the earlier case, the time to meeting is calsulated using the component of the vector speed of the vessel that is parallel to the ferry track and all of the interactions will be classified as a front interaction.

If $\theta_{BACK} < \theta < \theta_{FRONT}$ and $-\theta_{BACK} < \theta < -\theta_{FRONT}$, the time to interaction will be the time to crossing if the vessels have not crossed each other, otherwise it will be the time that has elapsed since the vessels crossed each other. In both of these cases, if the future (past) ferry position is infront of the future (past) ferry position during crossing, then it's back interaction. Otherwise, it's a front interaction. With this model, the closest other traffic will be based on the minimum time to interaction.

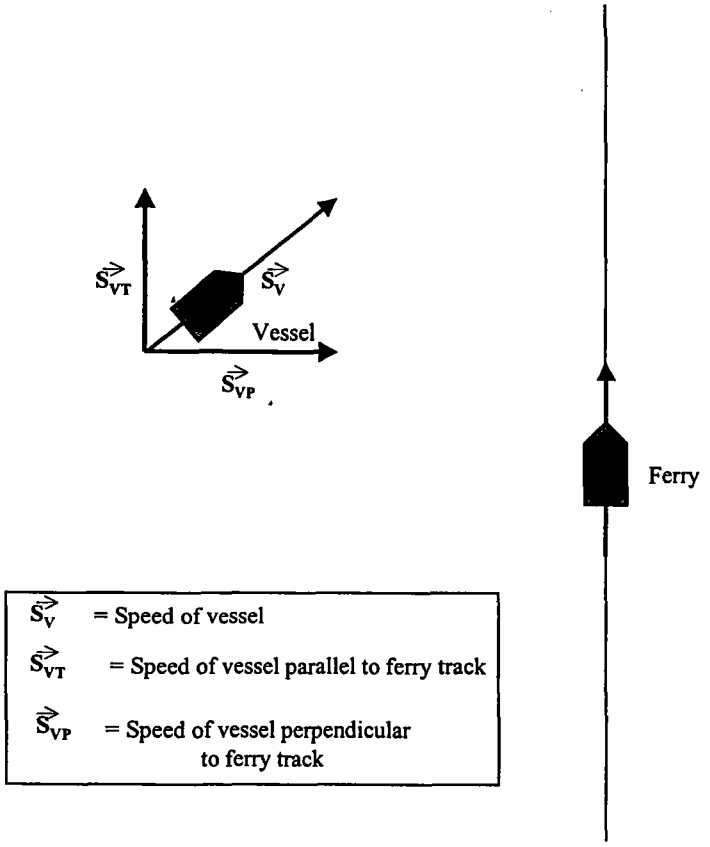



**Fig. 7** Component of Vector Speed

Finally, if a ferry is underway within a five minute period with no other vessels interacting, it will be considered as an OFI (alone) as some probability of an accident are based on time in the system. In all the cases define above, the 2.5 minute period is used so that interactions could be accounted for, which might have been missed had a longer interval been used. It is judged that the above models would be sufficient/reasonable to account for most, if not all of the interactions present in the WSF system.

## 4. Conclusion

When limited or no data is available, the model and the methodology presented in this paper provides a means for estimating the number of accidents in a maritime system. Once the OFIs have been defined, not only can they be counted, but associated variables that may be

considered contributing risks factors such as wind speed, wind direction and visibility (situational variables) can be recorded for each OFI. This in turn can be used to assess the likelihood of triggering events and collision (accident) given the variables describing a particular OFI as in Szwed et al [4]. This methodology might be useful for rare events risk analysis in other application and other discipline as well.

## References


1. B.J. Garrick. Recent Case Studies and Advancement in Probabilistic Risk Assesment, *Risk Analysis*, 4 (4), (1984), 267-279.

2. M. Grabowski, J.R.W. Merrick, J.R. Harrald, T.A. Mazzuchi and J.R. van Dorp. Risk Modeling in Distributed, Large-Scale Systems, *IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans,* 30(6), (2000), 651-660.

3. J. Harrald, R. Van Dorp, T. Mazucchi, I. Renda-Tenali, S. Shrestha, N. Abdul Ghani. *The Washington State Ferries Risk Assessment Final Report,* (1999), 69 pages.

4. P. Szwed, J. Rene van Dorp, J.R.W. Merrick, T.A. Mazzuchi and A. Singh. A Bayesian Paired Comparison Approach for Relative Accident Probability Assessment with Covariate Information, *European Journal of Operations Research*, 161 (1), (2004), 240-255.

5. http://www.puget_sound_regional_council.org