

Waterway Management and the Operation of High-Speed Ferries

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Introduction

There are approximately 70 high-speed ferries currently operating in the United States and it is expected that this number will continue to increase over the near- and mid-term. Much of the current interest in high-speed vessels is to provide an alternative transportation mode that can compete against the other surface modes – car, bus and rail. In some areas high-speed vessels are also competing against short air routes. High-speed vessels are also being considered as an alternative to trucks for moving freight along the Eastern Seaboard. Fueling the interest in high-speed ferries is the recognition of many transportation planners that roadways are becoming increasingly congested and that land-based transportation systems will not be able to accommodate future demands. However, for water transportation to be a viable alternative to either road or rail, vessels will need to operate at service speeds that provide transit times that are competitive with these other modes.

On going advances in vessel design and propulsion systems are making it possible for vessels to achieve increasingly higher operating speeds and make water transport more competitive with other the other modes. Although operating speeds in excess of 35 to 40 knots are possible, there is concern that the operation of vessels at higher speeds may increase the risk of collision. There are two reasons for this concern. The first is related to vessel speed since as vessel speed increases the time available after another vessel is detected to assess whether a risk of collision exists, develop a course of action to avoid collision, and finally to execute it decreases. The second is related to the forecast increase in both the number of high-speed ferries as well as other commercial and recreational vessels operating on the Nation's waterways. An analysis of vessel speed on time to the closest point of approach (CPA) was conducted to establish an objective basis from which to assess potential risks of higher vessel operating speeds on safe navigation as well as how those risks might be mitigated.

Impact of Vessel Speed on Time to CPA

Method and Assumptions

The time to CPA was calculated for three situations recognized in the International Regulations for the Prevention of Collisions at Sea, 1972 (72 COLREGS) and the Inland Navigation Rules: overtaking (Rule 13), head-on or meeting (Rule 14), and crossing (Rule 15).¹ For the purpose of this analysis it was assumed that both vessels are power-

¹ Rules 13, 14 and 15 are the same in both the 72 COLREGS and the Inland Navigation Rules. Unless otherwise noted, all references to specific navigation rules will refer to the 72 COLREGS.

driven.² The calculation was done based on a range of 2 nautical miles (NM) between the two vessels at the time of detection. Two nautical miles was selected since it is a probable range at which the operator of a high-speed vessel is likely to detect and monitor small commercial and recreational vessels. For the purpose of this analysis it is assumed that visibility is not restricted, in other words Rule 19 does not apply.

The time periods used to evaluate the time to CPA are 3 and 6 minutes. These periods were chosen since mariners commonly use them when manually plotting contacts on radar to assess whether the risk of collision exists. These are also the periods of time an operator of a vessel not fitted with radar might reasonably need to determine if risk of collision exists using visual bearings.

Many commercial vessels, including most high-speed vessels, are fitted with an automatic radar plotting aid (ARPA). Upon establishing steady state tracking, an ARPA must calculate the range of CPA within 1 minute and the time to CPA within 3 minutes.³ However, the operator of a vessel fitted with an ARPA unit cannot, nor should, rely exclusively on it to track other vessels. This is particularly true for vessels such as sea kayaks or other small recreational vessels that might reasonably be detected and tracked only under certain favorably conditions. In addition, it must be remembered that all vessels are obligated by Rule 5 to maintain a proper lookout to determine if the risk of collision exists. Although vessels fitted with operational radar are required by Rule 7(b) to use it, radar and ARPA are tools intended to supplement the lookout.⁴ Therefore, it is appropriate to evaluate the time to CPA using these traditional periods.

For each of the three situations it was assumed that risk of collision existed. In accordance with Rule 7(d), the risk of collision must be considered to exist when the bearing between two vessels does not change while the range decreases. There are two reasons for making this assumption. First, it focuses the analysis on the impact higher vessel speeds have on the period of time that is available to determine if the risk of collision exists as well as to develop and execute a course of action to prevent collision if the risk is deemed to exist. Second, by assuming that the risk of collision exists, it is not necessary to consider what constitutes a minimum safe passing distance.

² The obligations established for head on (Rule 14) and crossing (Rule 15) situations are applicable only when both vessels are power-driven vessels.

³ The technical performance requirements for ARPA units are found at 33 C.F.R. § 164.38 Appendix A. Steady state tracking means that the target can be tracked 5 out of 10 sweeps of the radar antenna. Traditional marine radar antennas rotate at approximately 22 – 26 rpm. Radar antennas intended for installation on high-speed vessels (speeds higher than 30 – 35 kts) rotate at approximately 36 – 42 rpm.

⁴ Raymond F. Farwell, *Farwell's Rules of the Nautical Road*, 7th ed., ed. Richard A. Smith (Annapolis, MD: Naval Institute Press, 1994), 196.

Analysis

Overtaking Situation

An overtaking situation exists when a vessel is “coming up with another vessel from a direction more than 22.5 degrees abaft her beam.” Per Rule 13(b) such a situation exists when only the sternlight of the vessel being overtaken can be seen from the other vessel. Clearly, an overtaking situation can exist only when the speed of the vessel being overtaken is less than the speed of the overtaking vessel. Therefore, the higher speed vessel, that is the overtaking vessel, is obligated by Rule 13(a) to keep out of the way of the vessel being overtaken.

The closing rate for an overtaking situation when both vessels are on the same or nearly same course and the risk of collision exists is calculated by subtracting the speed of the vessel being overtaken from the speed of the overtaking vessel. For example, the closing rate between a vessel making 10 knots that is being overtaken by a vessel making 35 knots is 25 knots. Time to CPA is determined by dividing the range by the closing rate. Therefore, whereas an increase in the speed of the overtaking vessel will decrease the time to CPA, an increase in the speed of the vessel being overtaken will increase the time to CPA.

Table 1 shows the time to CPA when a vessel is being overtaken from directly astern. A review of this table clearly indicates that the time to CPA is reduced as the difference between the speed of the vessel being overtaken and the speed of the overtaking vessel increases. The time to CPA is greater than 6 minutes when the speed difference between the two vessels is 20 knots or less. The time to CPA is between 3 to 6 minutes when the speed difference between the two vessels is greater than 20 knots but less than 40 knots and 3 minutes or less when the speed difference is 40 knots or more. Since most high-speed vessels in the United States currently operate at speeds between 30 and 40 knots, vessels that will most likely be overtaken within approximately 3 minutes or less will probably be smaller commercial vessels and a significant portion of the recreational fleet. It is also likely that many of these vessels are not fitted with radar and that those vessels that may have radar will more than likely not have ARPA.

Table 1: Time (min) to CPA Overtaking Situation (Range of Detection 2 NM)

Overtaking Vessel (kts)	Vessel Being Overtaken (kts)						
	5	10	15	20	25	30	
30	4.8	6.0	8.0	12.0	24.0		
35	4.0	4.8	6.0	8.0	12.0	24.0	
40	3.4	4.0	4.8	6.0	8.0	12.0	
45	3.0	3.4	4.0	4.8	6.0	8.0	
50	2.7	3.0	3.4	4.0	4.8	6.0	
55	2.4	2.7	3.0	3.4	4.0	4.8	
60	2.2	2.4	2.7	3.0	3.4	4.0	
65	2.0	2.2	2.4	2.7	3.0	3.4	
70	1.8	2.0	2.2	2.4	2.7	3.0	
	X.X	Time to CPA 3 minutes or less					
	X.X	Time to CPA between 3 and 6 minutes					

Head-On Situation

A head-on, or meeting, situation exists when two vessels are meeting on reciprocal or nearly reciprocal courses and the risk of collision exists (Rule 14). Per Rule 14(b), a meeting situation exists “when a vessel sees the other ahead or nearly ahead and by night she could see the masthead lights of the other in a line or nearly in a line and/or both sidelights and by day she observes the corresponding aspect of the other vessel.” In accordance with Rule 14(a), both vessels are required to alter course to starboard so that each vessel passes to the port side of the other.⁵ Both vessels have an obligation to act accordingly if there is doubt whether a meeting situation exists.

The time to CPA in a meeting situation is dependent on the closing rate between the two vessels, which is calculated by adding the speeds of the two vessels. For example, the closing rate between a vessel with a speed of 20 knots and another vessel with a speed of 35 knots is 55 knots. Any increase in either vessel’s speed will increase the closing rate and as a result reduce the time to CPA. Similarly, a decrease in either vessel’s speed will reduce the closing rate, which will increase the time to CPA.

Table 2 shows the time to CPA for a meeting situation when the range to detection is 2 NM. For all closing rates greater than 35 knots, the time to CPA is 3 minutes or less. This is significant insofar as the closing rate in a meeting situation between a high-speed vessel and almost any other vessel can reasonably be expected to be 35 knots or more. This highlights the importance of maximizing the range of detection between vessels that may be involved in a meeting situation in order to increase the time available for both vessels to determine if the risk of collision exists and, if necessary, maneuver to avoid collision.

Table 2: Time (min) to CPA Head-On Situation (Range of Detection 2 NM)

Faster Vessel (kts)	Slower Vessel (kts)					
	5	10	15	20	25	30
30	3.4	3.0	2.7	2.4	2.2	2.0
35	3.0	2.7	2.4	2.2	2.0	1.8
40	2.7	2.4	2.2	2.0	1.8	1.7
45	2.4	2.2	2.0	1.8	1.7	1.6
50	2.2	2.0	1.8	1.7	1.6	1.5
55	2.0	1.8	1.7	1.6	1.5	1.4
60	1.8	1.7	1.6	1.5	1.4	1.3
65	1.7	1.6	1.5	1.4	1.3	1.3
70	1.6	1.5	1.4	1.3	1.3	1.2
	X.X	Time to CPA 3 minutes or less				
	X.X	Time to CPA between 3 and 6 minutes				

⁵ It should be noted that the Inland Navigation Rules include the phrase “Unless otherwise agreed...”

Crossing Situation

Per Rule 15, a crossing situation exists when “two power-driven vessels are crossing so as to involve a risk of collision.” In other words, a crossing situation exists when a vessel is coming up on another from a direction less than 22.5 degrees abaft the other’s beam and there is a risk of collision. In a crossing situation the vessel that has the other vessel on its own starboard side is the give-way vessel and is required by Rule 15 “to keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel.” The give-way vessel is required by Rule 16 to “take early and substantial action to keep well clear” of the other vessel, which is the stand-on vessel. The stand-on vessel, in accordance with Rule 17, may under certain circumstances maneuver to avoid collision.

The closing rate in a crossing situation is calculated by adding the speed vectors of the two vessels. For the purpose of this analysis it was assumed that the speed vectors formed a right triangle so that the closing rate could be calculated using a quadratic equation. The time to CPA is then calculated by dividing the range of detection by the closing rate. Although the closing rate is a function of the speeds of both vessels, it was assumed for this analysis that the high-speed vessel was the give way vessel. However, the time to CPA is the same if the high-speed vessel is the stand on vessel.

The time to CPA is shown in Table 3. Except for a few cases when the high-speed vessel is operating at speeds of 35 knots or less, the time to CPA is less than 3 minutes. This is significant insofar as it provides relatively little time for the operator of the stand-on vessel, which may or may not be another high-speed vessel, to evaluate the actions of the give-way vessel and to maneuver as permitted by Rule 17 if it is determined that the actions of the give-way vessel are not sufficient to avoid collision. Given the short period of time available, it is particularly incumbent upon the give-way way vessel to “take early and substantial action to keep well clear” as required by Rule 16 and that any changes in course and speed be large enough that they are immediately apparent (Rule 8). Lastly, it should be noted that close examination of Table 3 also shows that as the speed of the high-speed vessel increases the impact of the speed of the slower vessel on the time to CPA decreases.

Table 3: Time (min) to CPA Crossing Situation (Range of Detection 2 NM)

Give-Way Vessel (kts)	Stand-On Vessel (kts)					
	5	10	15	20	25	30
30	3.9	3.8	3.6	3.3	3.1	2.8
35	3.4	3.3	3.2	3.0	2.8	2.6
40	3.0	2.9	2.8	2.7	2.5	2.4
45	2.7	2.6	2.5	2.4	2.3	2.2
50	2.4	2.4	2.3	2.2	2.1	2.1
55	2.2	2.1	2.1	2.1	2.0	1.9
60	2.0	2.0	1.9	1.9	1.8	1.8
65	1.8	1.8	1.8	1.8	1.7	1.7
70	1.7	1.7	1.7	1.6	1.6	1.6
	X.X	Time to CPA 3 minutes or less				
	X.X	Time to CPA between 3 and 6 minutes				

Summary

Based on the analysis it can be concluded that higher vessel operating speeds can increase the risk of collision insofar as they do reduce the time available after another vessel is detected to assess whether a risk of collision exists, develop a course of action to avoid collision, and finally to execute it. The analysis also shows the benefit of increasing the range of detection insofar as this will provide additional time to CPA. It also highlights the importance of maintaining a good look-out and of taking early and substantial action to avoid collision.

Mitigating the Risk – Issues to Consider

There are several factors that need to be considered when determining how to best mitigate the potential increased risk of collision associated with higher vessel operating speeds. These include maintaining a balance between the competing goals of safety and mobility, the forecast increased use of the Nation's waterways, and the need to accommodate the different needs and different capabilities of all waterway users.

Competing Goals

For the Nation's transportation system to realize the benefits of high-speed vessels, the operation of these vessels must be safe, efficient, reliable, and environmentally responsible. This requires establishing and maintaining a balance between acceptable levels of safety, mobility, and environmental protection. Establishing and maintaining this balance means that tradeoffs will need to be made in one area in order to achieve an acceptable level in another. The implication, which is illustrated in Figure 1, is that some level of risk to safety, mobility, or natural resources is inherent in the operation of high-speed vessels. However, this situation is not unique to high-speed vessels. Rather, it is a reality associated with the operation of any type of commercial or recreational vessel. There is no single solution for how to optimize the balance between these competing goals. Therefore, what constitutes an appropriate solution for mitigating risk on one waterway may not be appropriate for another.

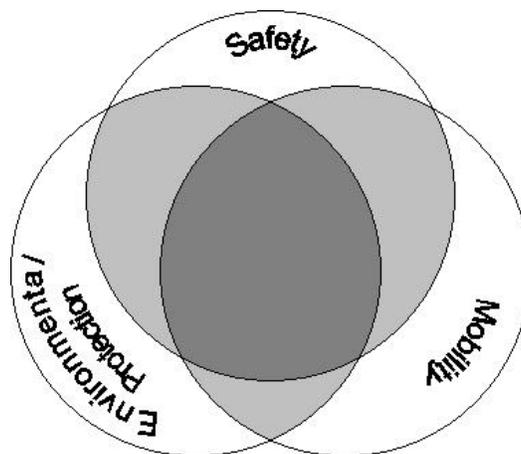


Figure 1: Balancing Competing Goals

Addressing waterway management issues related to the operation of high-speed vessels requires identifying factors that can potentially have a negative impact on any one of the strategic goals. Once those factors are identified, it is then necessary to determine how to mitigate that potential impact without having an undue impact on another goal. When selecting mitigation measures, it is also necessary to identify the needs of other waterway users and to determine how those needs may be impacted. Therefore, an appropriate mitigation measure must effectively mitigate a negative impact on one strategic goal without having an undue impact on either another goal or particular group of waterway users.

Increased Use of the Nation's Waterways

Another factor that must be considered is that the Nation's waterways are increasingly being used for both commerce and recreation. Although some of this increased usage is the result of the growth of the high-speed ferry fleet, it is expected that there will also be significant growth in the number of other commercial and recreational vessels. Any mitigation measures that are adopted must be able sufficiently flexible to accommodate this growth. Increased usage may also mean that traffic volume must be periodically evaluated to determine whether existing mitigation measures are adequate and or whether additional measures are needed.

Different Needs and Different Capabilities

Although the focus of most discussions has been on the high-speed vessel, it must be remembered that the presence of high-speed vessels on a waterway also impacts the operation of non-high-speed vessels. In addition, the operation of high-speed vessels also impacts both commercial and recreational waterway users. The implication is that any mitigation measures that may be considered must take into account both the needs and the capabilities of the different waterway users that will reasonably encounter a high-speed vessel.

Shared Responsibility

The responsibility for addressing risks to waterway safety associated with the operation of high-speed vessels is properly shared by high-speed vessel operators and the Coast Guard as well as by other commercial and recreational vessel operators. This point is recognized by the IMO High-Speed Craft Code: "In developing this Code, it has been considered desirable to ensure that high-speed craft do not impose unreasonable demands on existing users of the environment or conversely suffer unnecessarily through lack of reasonable accommodation by existing users."⁶ Provided the membership is sufficiently broad so that the interests of all waterway users are represented, harbor safety committees provide an excellent forum for determining whether additional mitigation mechanisms are required as well as for identifying which mechanisms may be appropriate for a particular waterway. In other ports, it may be necessary to conduct public workshops that are open to all interested parties.

⁶ International Maritime Organization, *International Code of Safety for High-Speed Craft* (London, 1995), Preamble § 14.

Mitigating the Risk – Some of the Options

There are a number of different options for mitigating the risk to navigation safety associated with the operation of high-speed vessels. These options can be grouped into one of three general categories:

- Vessel operation and equipment;
- Vessel traffic management; and,
- Education and outreach.

Whereas some of the mitigation options can be implemented independently by vessel operators, others will require coordination with other waterway users as well as with the Coast Guard.

Vessel Operation and Equipment

A primary focus of the mitigation options related to vessel operation and equipment is to improve both the likelihood that other vessels will be detected as well as the range of detection. How this is accomplished is, to some extent, specific to the type of vessel being considered. It is not expected, nor is it practical, for small recreational vessels to carry the same equipment that it is reasonable to find on board a high-speed commercial vessel. For example, high-speed vessels operating on a congested waterway should carry two radars appropriate for the vessel's operating speed.⁷ They may also consider using night vision equipment.⁸ In contrast, recreational vessels may be fitted with radar reflectors to improve the vessel's radar signature, which can increase both the likelihood and range of detection.

Ensuring that a proper look-out is maintained will also increase the likelihood of detecting other vessels. Rule 5 of both the 72 COLREGS and the Inland Navigation Rules require that "every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision." It should be noted that although vessel size may be used to determine what constitutes a proper lookout,⁹ no such differentiation exists *vis-à-vis* the requirement to maintain a look-out. With the exception of small vessels, it is expected that the look-out will not have any other responsibilities.

The risk of collision can also be mitigated through operational practices. For example, operators of recreational vessels can reduce the potential of collision with a high-speed vessel by, to the extent practicable, operating away from high-speed commercial vessels. Similarly, high-speed vessels should also attempt to avoid areas with large concentrations of recreational vessels. Operators of high-speed vessels can also reduce the risk of

⁷ The two radar standard is included in U.S. Coast Guard Navigation and Vessel Inspection Circular 5-01 (NVIC 5-01).

⁸ Although the IMO High-Speed Craft Code does not require the carriage of night vision equipment, it recommends this equipment be fitted if justified by "operational conditions." (IMO HSC Code § 13.10.1).

⁹ Farwell's, p. 236.

collision by repeatedly using the same route so that other vessel operators can predict where they may expect to encounter high-speed vessels.

Vessel Traffic Management

Vessel traffic management measures can be used to reduce the likelihood of collision between vessels of all types, including with high-speed vessels. In contrast to mitigation measures based on vessel operation and equipment, which are vessel specific, vessel traffic management is focused on the waterway and the composition of vessels that use it. In addition, whereas mitigation measures based on vessel operation and a vessel operator can implement mitigation measures based on equipment independently, the implementation of vessel traffic management regimes requires regulatory action by the Coast Guard.

The primary means of managing vessel traffic on the Nation's waterways are the navigation rules. These rules establish universal requirements describing what vessels shall do to detect the presence of other vessels and to determine whether the risk of collision exists. They include the requirement to maintain a look-out (Rule 5), how to determine whether the risk of collision exists (Rule 7), and the obligation to operate at safe speed (Rule 6). The navigation rules also mandate how vessels shall be maneuvered to avoid collision when such risk is deemed to exist (Rules 13 – 17).

Vessel traffic can also be managed through the use of routing measures. Routing measures can reduce the likelihood of collisions by establishing predictable traffic patterns as well as by separating vessels of different types. Although draft or tonnage is most commonly used to distinguish between vessel types, speed could also be used for this purpose. Determining which type of scheme is most appropriate requires an assessment of both the physical characteristics of the waterway as well as of the types and volume of vessels that use it. Compliance with a given routing measure can be either mandatory or voluntary.

In addition to requiring that certain types of vessels follow designated lanes, others vessels can be prohibited from operating inside of the lane except when necessary to cross it.¹⁰ The implication is that, although traffic lanes are an effective means of reducing the potential of collisions, they can also reduce the area of a waterway available to different waterway users. This is particularly true in areas where compliance is compulsory and other vessels are prohibited from operating inside of designated lanes. Therefore, before routing measures are implemented, it is necessary to ensure that potential benefits more than offset their potential adverse impacts.

Another method of managing vessel traffic is to impose restrictions on vessel speed. Restrictions on vessel speed can reduce the likelihood of collision by lowering the relative speed between vessels and increasing the time to CPA. Although speed restrictions can be an effective tool for managing vessel traffic, such restrictions should

¹⁰ Rule 10 of both the 72 COLREGS and the Inland Navigation Rules require...

generally only be considered in areas with high volumes of vessels with large speed deltas and where it is not practical to use traffic lanes to separate vessels of different types. Although speed restrictions can be used to manage vessel traffic, care must be used when establishing speed limits to avoid creating problems with wake wash.¹¹

Education and Outreach

Education and outreach can also contribute to reducing the likelihood of collision. In addition to ensuring that their crews are fully familiar with the vessel's maneuvering characteristics and navigation equipment, which is the focus of most training programs, high-speed vessel operators must also ensure that their crews develop a "high-speed" mindset. A high-speed mindset requires having a thorough understanding of how vessel higher operating speeds can increase the risk of collision as well as the need to take early and substantial action when appropriate to avoid collision. It also requires having some understanding of the concerns other vessel operators may have when operating in the vicinity of high-speed vessels.

In addition to training their own crews, high-speed vessel operators should also engage in outreach to other waterway users. The intent of outreach is twofold. First, it provides an effective mechanism for identifying the concerns of other waterway users as well as to develop measures to address them. Second, outreach provides an opportunity to inform other waterway users about the operational capabilities of high-speed vessels, which can go a long way toward addressing the uncertainties that can result in efforts to oppose the expanded employment of high-speed vessels. Forums for outreach include organizations with a broader focus, such as harbor safety committees, or ad hoc or formal groups established for this specific purpose.¹²

Conclusion

There is a risk of collision associated with the operation of high-speed vessels insofar as higher operating speeds do reduce the time available after another vessel is detected to assess whether a risk of collision exists, develop a course of action to avoid collision, and finally to execute it. However, the risks associated with higher operating speeds can be mitigated using both regulatory and non-regulatory tools and requires the participation of high-speed vessel operators, other waterway users, and the Coast Guard. How these risks are addressed will vary based on the physical characteristics of a particular waterway as well as on the volume and type of vessels that use it in order to maintain an acceptable balance between safety, mobility and environmental protection. Effectively addressing these risks is necessary so that vessels can operate at service speeds that provide transit times that are competitive with other modes transportation modes and so that the Nation can fully realize the benefits of water transportation.

¹¹ For a discussion of the relationship between vessel speed and wake wash see Stanley C. Stumbo, et al., "The Prediction, Measurement and Analysis of Wake Wash from Marine Vessels," *Marine Technology*, Vol. 36 (1999), pp. 249.

¹² The Long Island Sound High-Speed Ferry Working Group (<http://www.fastferryinfo.org>) is an example of a group established for this purpose.