Standardization of Risk Assessment in Navigation

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Abstract. Marine traffic safety assessed by quantitative instead of qualitative methods is increasingly required. There are mature methods available to conduct a quantitative risk assessment such as IWRAP [1], resulting in collision and grounding probabilities. There is, however, the difficulty to determine the so-called causation factor having an impact on the results but there is currently no reliable method to fix it. To globally collect relevant empirical data to allow a statical determination could make risk analysis results less questionable but comparable.

1. Introduction

Formal requirements and public sensitivity increasingly focus on marine traffic safety in coastal areas. Times are over when ships simply could navigate where water depth al-lows. Nowadays a wide range of interest groups stick out their hands to exploit coastal zones or to prevent from exploitation including shipping to preserve nature. In busy sea areas traffic lanes become increasingly squeezed and an increased exploitation level may result in an increased risk of ships to collide with fixed or floating objects or to ground. To ensure safe vessel traffic, navigational risks must be known. One can only manage what can be measured.

Methods to assess navigational risk mean-while escaped the nursery. There are qualitative methods identifying possible hazards and mitigation options jointly with a rough estimation of consequences and quantitative methods to more accurately calculate risks based on specified risk scenarios (risk models). Authorities increasingly ask for a quantitative approach.

The definition of risk is

Risk = probability x consequences
[annual frequency x average costs]

It is cumbersome but achievable to capture consequence costs, especially when insurance providers support. For comparison purposes collision and grounding probabilities often are sufficient as long as ship types and cargoes do not differ too much.

2. Quantitative Assessment of Navigational Risk

The International Maritime Organization (IMO) published "Guidelines for formal Safety Assessment (FSA) [2], a structured and systematic methodology to be used as a frame-work to support in the evaluation of new regulations for maritime safety and protection of the marine environment or in comparing be-tween existing and projected regulations. For quantitative risk assessment IMO recommends applying the IALA Risk Management Tool for Ports and Restricted Waterways, the

IWRAP Mk2 tool [3] which allows to quantify the frequencies of collisions and groundings in any traffic area. As explained in the introduction, the probability of collisions and groundings is only one fraction of risk. In case of continuous risk assessment conducted to monitor the safety of a sea area or waterway it is sufficient to only once calculate the risk and then to restrict to probabilities for consecutive assessments as long as nature and composition of traffic does not significantly change.

The IWRAP-label “IALA Risk Management Tool….” is misleading as the tool allows only to determine collision and grounding frequencies but not consequence costs, which needs to become assessed separately based on input from IWRAP-results. This shall not deteriorate the enormous benefits of the tool. Whoever sat weeks to investigate collision and grounding frequencies manually, will certainly appreciate this extremely helpful tool, very efficiently to be used.

IWRAP is a probabilistic approach on the basis of geometric (spacial) distribution of traffic and navigational obstacles. The IWARP theory is described in [4]. The traffic distribution can become captured by AIS-counts of ships. To allow for mathematical processing a statistical distribution is selected which best fits the histogram-data of traffic (see fig. 1). Frequently a normal distribution can be ap-plied, however it depends on how the distribution matches the histogram-data and on the scenario to become investigated.

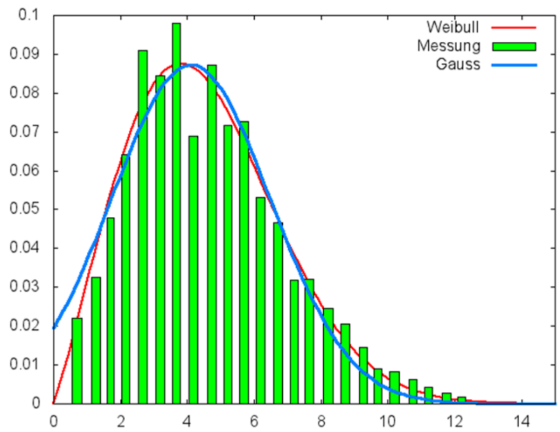

Figure 1: Traffic histogram and statistical distributions

3. Probability of Collisions

Risk models and formulae depend on the scenario describing encountering, overtaking, crossing or lane merging traffic, collisions between vessels and fixed obstacles or groundings. To elucidate the approach encountering traffic is used as an example below. Figure 2 shows the Fujii-model for encountering traffic and figure 3 the associated formula to calculate the collision frequency [5] [6].

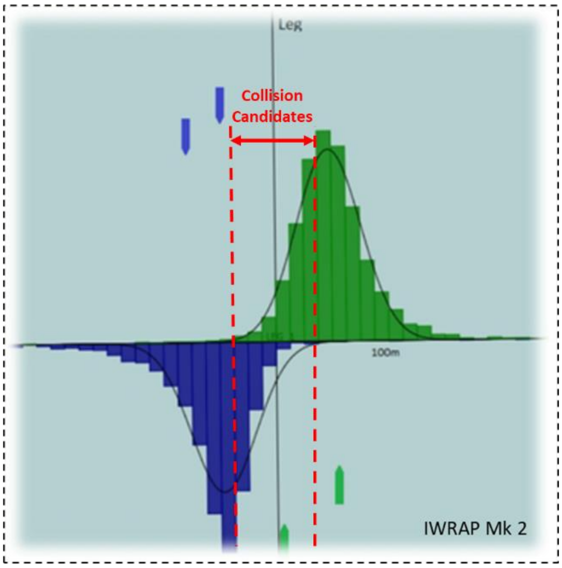

Figure 2: Fujii-Macduff-Model for encountering traffic

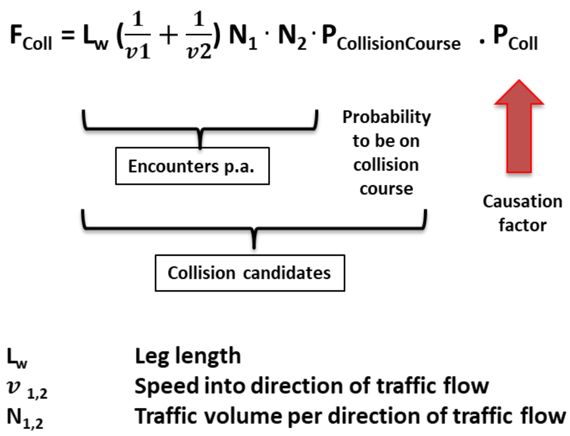

Figure 3: Collision frequency of encountering traffic (Fujii-Macduff) [7]

The elements of the formula are the encounters per time span, usually 1 year, and the probability to be on collision course, calculated on the basis of the AIS-counts providing the traffic distribution. The result shows the collision candidates, however, not all ships having the opportunity to collide, will do so. In the vast majority of cases on one or both ships an evasive action will be taken. Thus, the causation probability or causation factor is added to achieve the fraction of the collision candidates eventually colliding.

4. Causation Factor

The causation factor mirrors all possible human and technical collision causes, from human failure to steering failure. Recommended values can be found in literature [7]:

$P_{human} = 2 \cdot 10^{-4}$

$P_{steering} = 6.3 \cdot 10^{-5}$

$P_{propulsion} = 1.5 \cdot 10^{-4}$

IWRAP also provides default values for the causation probability. It seems, however, problematic to generalize the default factor. The conditions governing e.g., the human causation factor may be found in insufficient training, negligence, fatigue, attitude, illness or insobriety. It also depends on the bridge team management and organization of ships. It can be assumed that human failures on cruise vessels occur more seldom than on container feeder vessels with minimum manning and always running behind terminal arrival schedules. It can also be assumed that there is a dependence between weather conditions and human failure rates when e.g., in dense fog an otherwise competent and engaged navigator lacks experience in radar-based collision avoidance.

The most reliable way to determine the causation factor is from empirical data. Also, an analytical approach appears possible. There are suitable methods available, such as

Fault tree analysis

Failure mode and effect analysis

Bayesian believe network.

An analytical approach requires to consider all possible causes and conditions to individually estimate the particular likelihood of occurrence. As long as there are no statistical data available, this is extremely difficult and experience shows that usually the cumulated probability is considerably too high.

There is a better availability of empirical data from some of the technical failures, such as loss of propulsion or steering than from failure of navigational equipment such as e.g., RADAR.

It is obvious that the difficulty to determine the causation factor is the weakness of the quantitative assessment of navigational risk. The only way to improve the accuracy of the causation probability is to collect suitable empirical data to allow for statistical analysis.

5. Causation Factor Database

The causation probability depends on a wide variety of conditions. To reliably base causation factors on representative statistical data, traffic and incident data covering all relevant navigational conditions must be collected over some years. This is only possible by global cooperation. It is required to depict e.g.

- Waterway/sea area
  - Geometry (routes, exclusion zones, traffic separation schemes, regulations)
  - Underwater morphology
  - Current
  - Aids to navigation
- Traffic
  - Ship types
  - Ship dimensions
  - Ship speeds
  - Cargoes carried
  - Traffic distribution per ship class
- Environmental conditions
  - Wind
  - Seastate
  - Visibility
  - Ice
- Incidents
  - Types
  - Consequences

The format and content of the databank and the methods to retrieve results must follow an agreed standard.

Figure 4: Conditions contributing to the causation probability

By collecting appropriate data from all parts of the world such a databank would soon become sufficiently mature to deliver reliable causation factors on demand based on an equally standardized retrieval format describing the relevant conditions of the area. The capability and the reliability of causation factors will continuously improve over time.

There are already some marine traffic databases providing at least a fraction of the a.m. information, which could contribute. In Europe this is the European Marine Casualty Information Platform (ECIMP), operated by the European Maritime Safety Agency (EMSA) in Lisbon. Amended by a consequences database to easily retrieve damage costs of injuries/fatalities, material and environment by collisions and groundings a very powerful "Navigational Risk Database" could become generated making risk assessment easy and results reliable and comparable.

6. Conclusion

The reliability of quantitative assessment of the likelihood of collisions and groundings as part of the assessment of navigational risk depends on statistical data allowing determination of the causation factor mirroring the local navigational and traffic conditions. Reliable deductions from statistical data requires a sufficiently large statistical population, which usually is not available for a specific navigational area of interest. By collecting traffic data globally according to an agreed taxonomy of relevant parameters data shortcomings could become mastered allowing to significantly increase the reliability of quantitative risk assessment in navigation.

References

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