SeaWise

Scenario Identification and Test Case Generation for Autonomous shipping

FEASIBILITY STUDY

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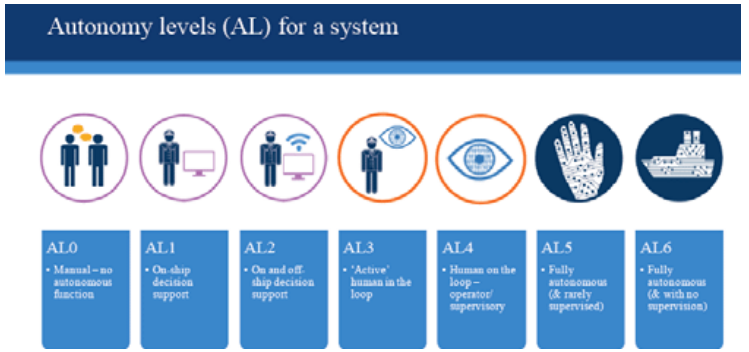
TNO innovation for life

NEED FOR SAFETY ASSESSMENT METHODOLOGY FOR AUTONOMOUS SHIPPING



- **Current situation:**
  - The required automation technology exists, however its reliability is insufficient
  - One way out is condition-based monitoring, very common in aeronautics
  - However, there always occur unforeseen circumstances where an instant reaction is required

- **Final goal:** Autonomous ships need to achieve a safety level equivalent to conventional ships based upon acceptable testing and validation methods

SeaWise BASED ON TNO StreetWise

- Automated mobility systems (or mobile robotics in general) are based on the same concepts and technology
- TNO has good expertise and practices in automated driving (StreetWise)

- **Final goal:** Autonomous ships need to achieve a safety level equivalent to conventional ships.
  - First step: to quantify system performance for critical situations as well as non-critical ones
  - Adoption of **StreetWise** methodology has the potential to reach this goal

NEED FOR 'NEW' SAFETY ASSESSMENT METHODS

FOR ADAS, TRADITIONALLY STRONG FOCUS ON ACCIDENT AND CRASH DATA

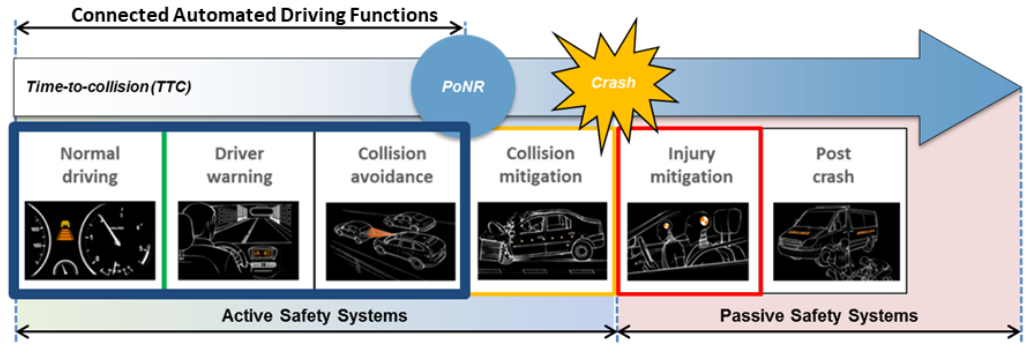
- To set up test protocol for rating
- To determine the performance of systems

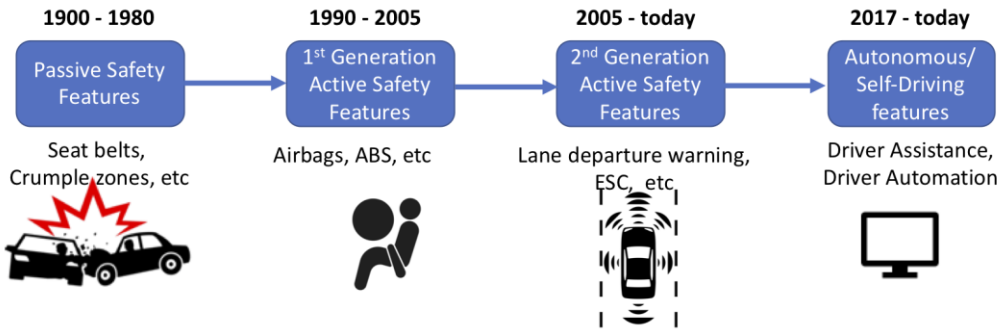
INCREASED NEED FOR ADDRESSING NORMAL EVERY DAY DRIVING

- To determine the performance on the road, not only in seldom critical/crash situations
- Holds for individual ADAS, but increasingly important to deal with the complexity of multiple simultaneously acting ADAS, especially in view of the transition towards higher levels of automation.

ESSENTIAL NEED FOR ROBUST AND EFFICIENT ASSESSMENT METHDOLOGY

- Test cases that check for system robustness are found from normal and every day driving
- However this need to be performed efficiently

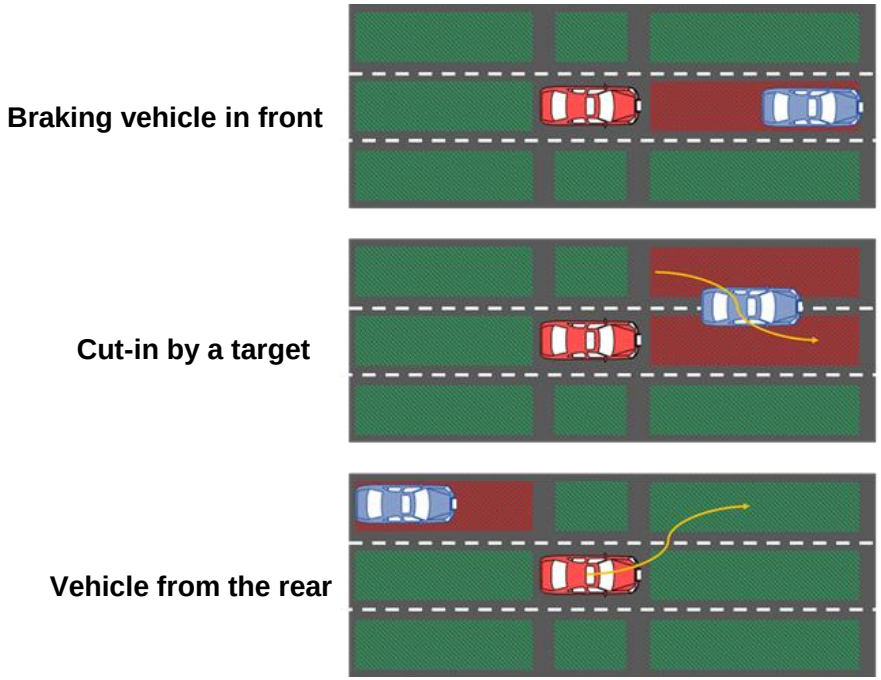


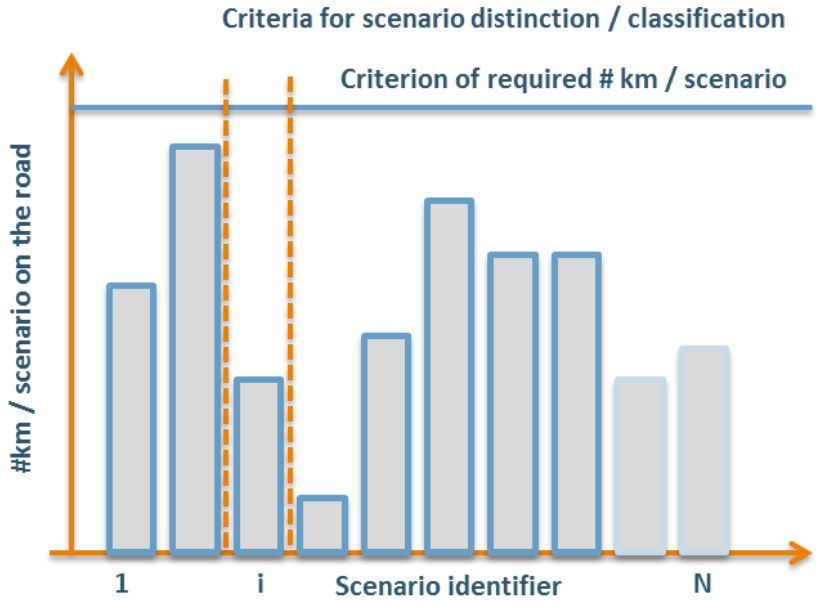


SCENARIO BASED APPROACH

INTERPRET TRAFFIC AS AN ENDLESS SEQUENCE OF DIFFERENT SCENARIOS

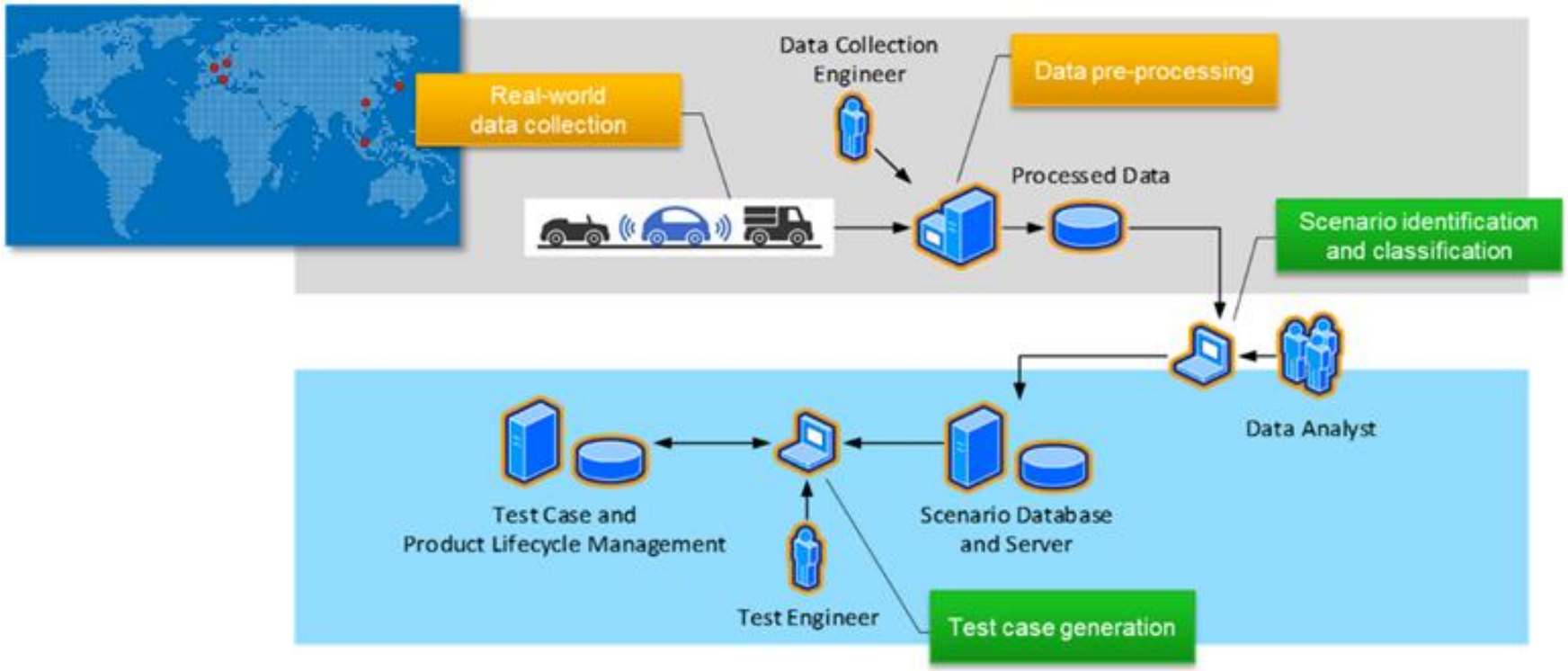
- Use library of scenarios in virtual testing for **development, testing** and **validation** of CAD systems
- **Scenario*:***
  - A scenario is a description of a situation that can happen or has happened in the real world. In other words, scenarios are used to describe any type of situation that a vehicle in operation can encounter during its lifetime.



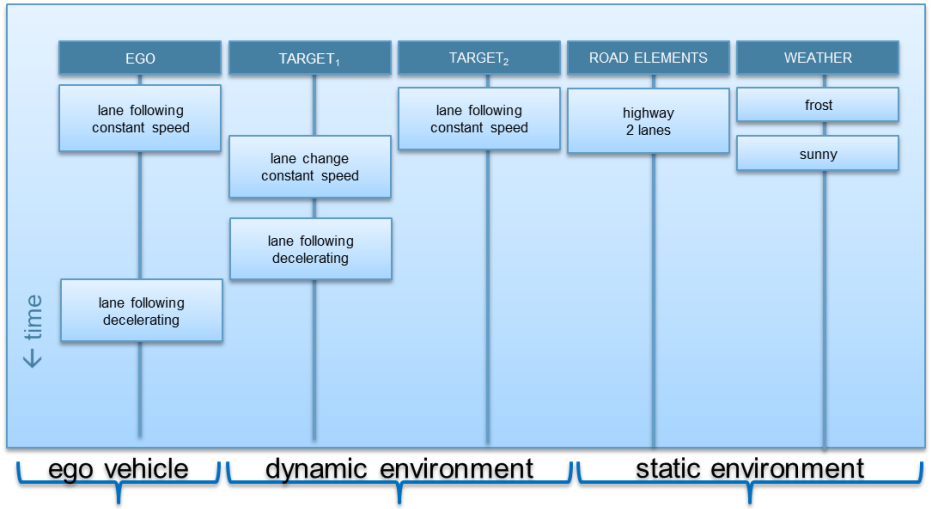


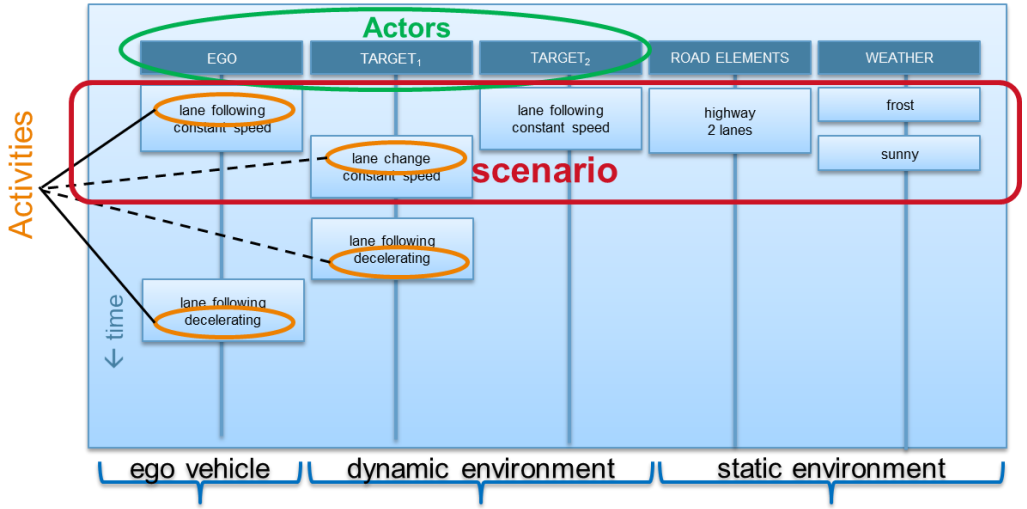
WORKFLOW

WWW.TNO.NL/STREETWISE



STREETWISE SCENARIO DEFINITION



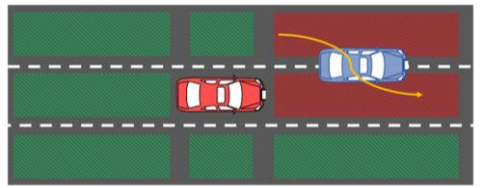


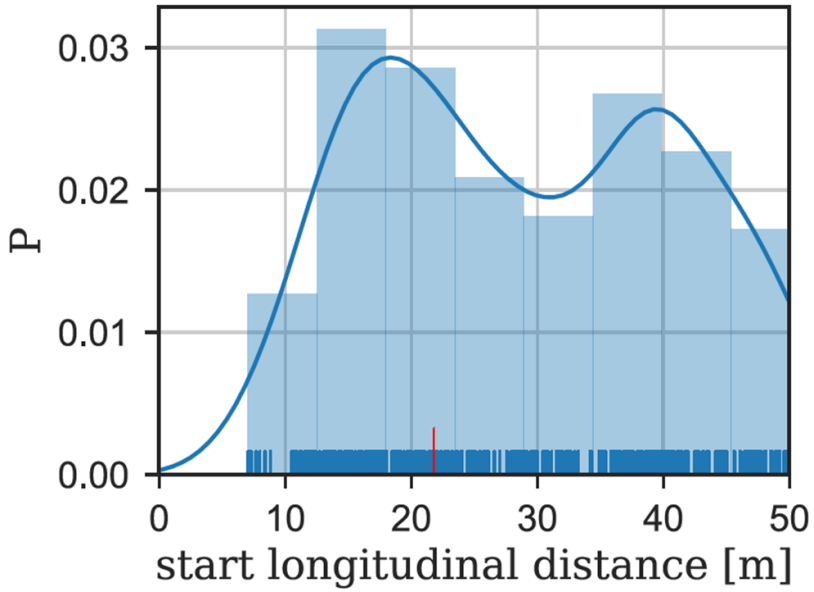
A SCENARIO

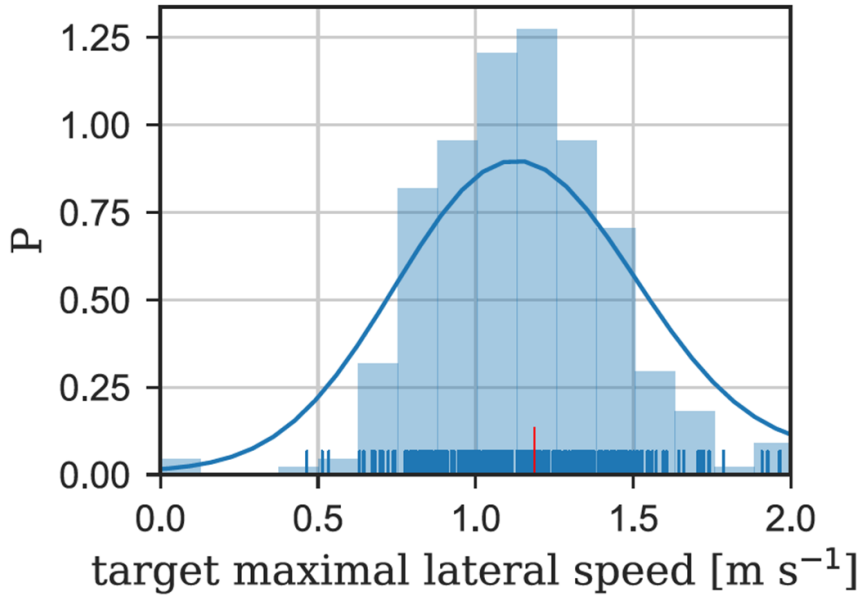
A scenario is a quantitative description of the ego vehicle, its activities and/or goals, its dynamic environment and its static environment. From the perspective of the ego vehicle, a scenario contains all relevant activities.

SCENARIO IDENTIFICATION & PARAMETERIZATION

- **Cut-in by a target**
  - Described by 4 parameters: ego vehicle speed, target vehicle speed, target lateral velocity, longitudinal distance between ego and target vehicle

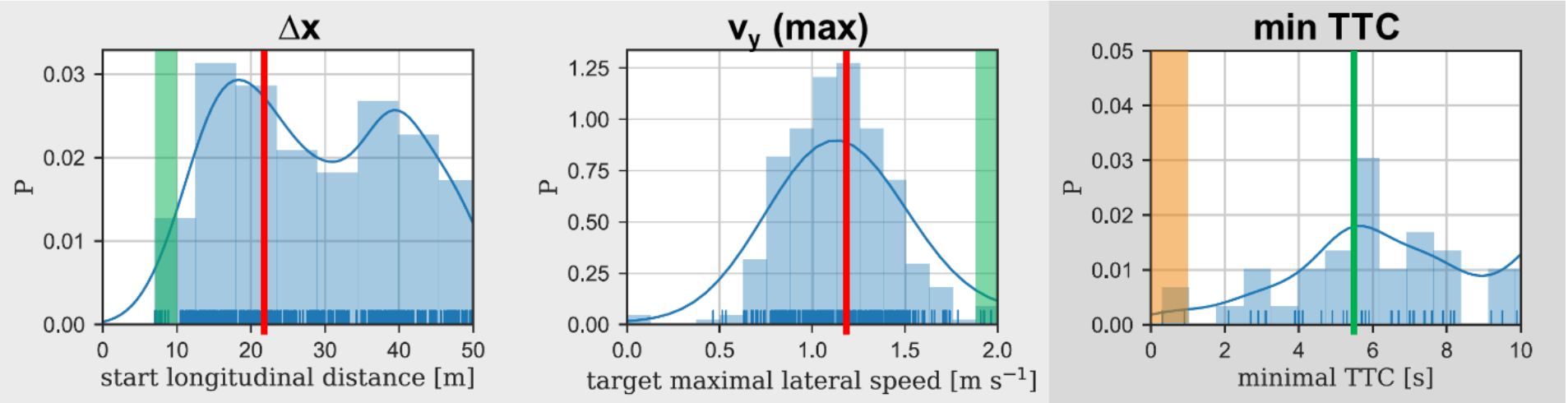






TEST CASE GENERATION

- Test case generation: sampling parameters within realistic ranges
- **Combination of parameter values might lead to critical situation:**
  - Start longitudinal distance
  - Target maximum lateral velocity
  - Minimal TTC (Time To Collision), minimal THW (Time HeadWay)
- Check with simulation tool whether combination leads to a physically realistic case.



OBJECTIVE OF SeaWise FEASIBILITY STUDY

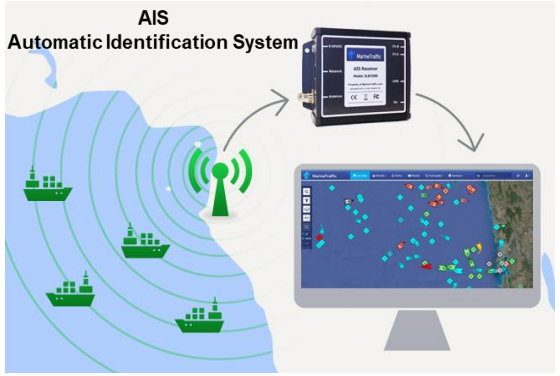
- Feasibility study to check whether the StreetWise methodology can be adopted by Autonomous Shipping to
  - develop a methodology "**SeaWise**" for generating 'real-life' seagoing scenarios for testing and assessing automated / autonomous sailing / shipping systems
  - investigate the feasibility of using AIS (**A**utomatic **I**dentification **S**ystem) data for extracting seagoing scenario

OUTCOME OF SeaWise FEASIBILITY STUDY

- It is easily possible for SeaWise to adopt the scenario definition of SteetWise and therefore
  - follow the general framework/pipeline of StreetWise
  - reuse StreetWise developed algorithms/scripts

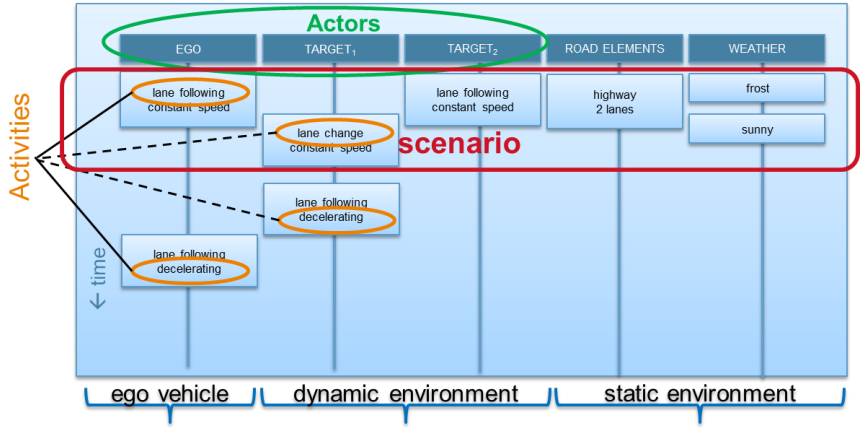
- However many challenges and differences must be taken into account
  - See next slide

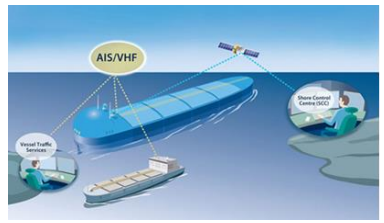
- AIS (**A**utomatic **I**dentification **S**ystem) data can be used to identify seagoing scenarios



SeaWise VS StreetWise

Scenario element	driving	sailing
Static environment	road	Sea → hydrodynamic
activity	simple heading ≈ cruising	complex heading ≠ curising
Operator per actor	One driver	Crew + engine room engineers
Scenario time scale	Seconds/minutes	Minutes/hours
Reactive time	seconds	minutes



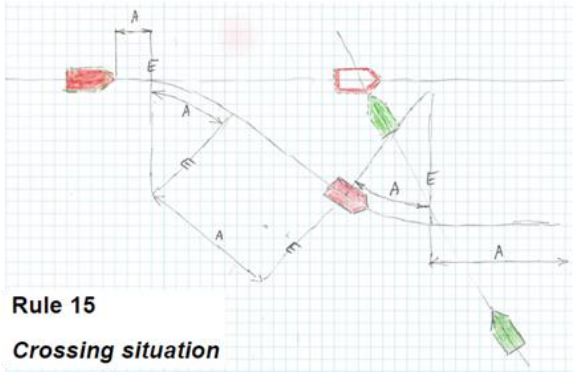


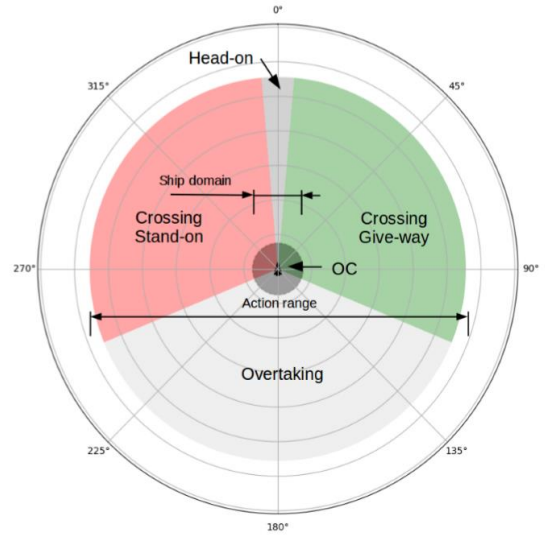
- Maritime domain is by definition Internationally regulated
- Availability of data → AIS data

SeaWise SCENARIO DEFINITIONS

- **SCENARIO**

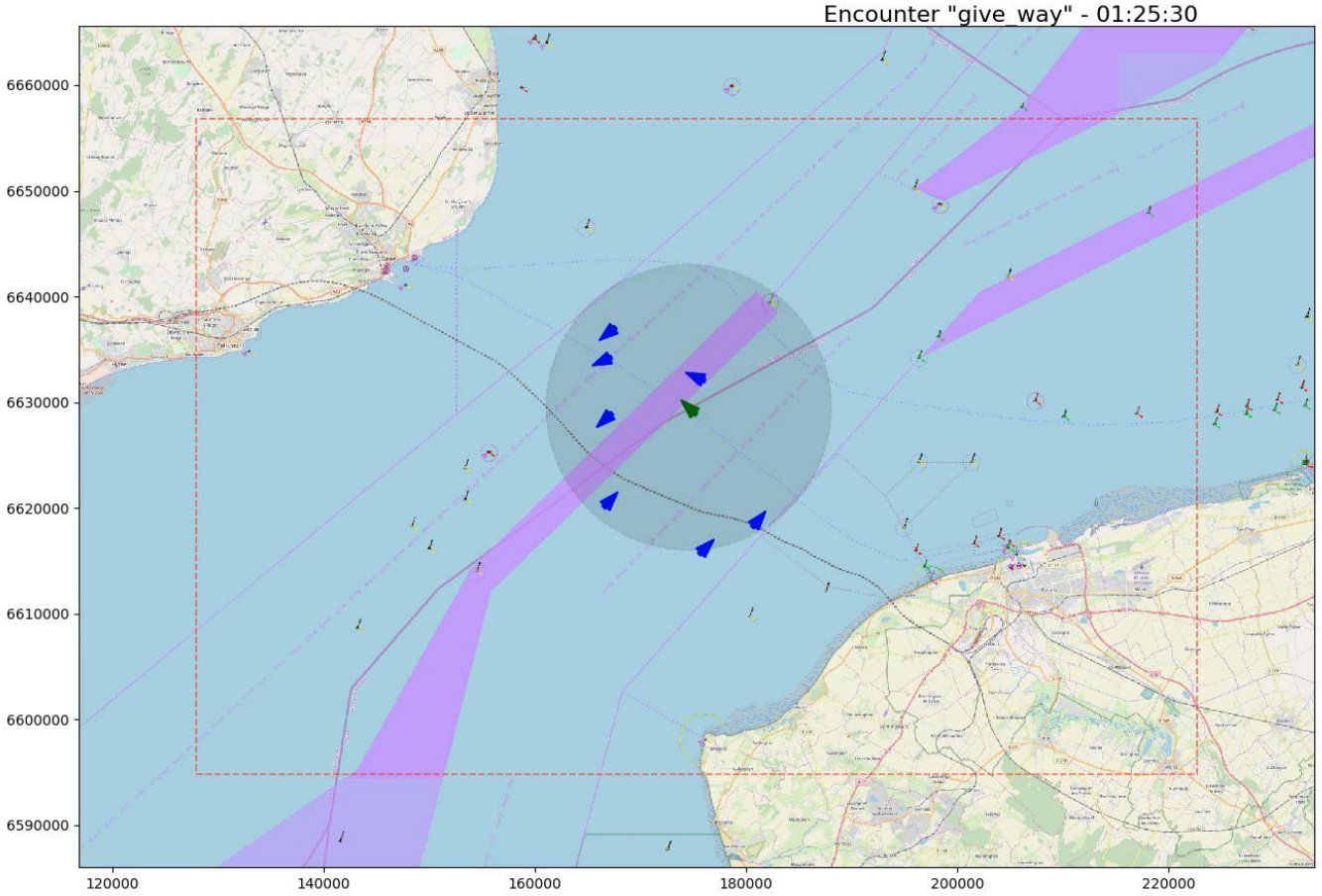
  A scenario is a quantitative description of the ego ship, its activities and/or goals, its dynamic environment and its ~~static~~ stationary environment. From the perspective of the ego ship, a scenario contains all relevant activities.

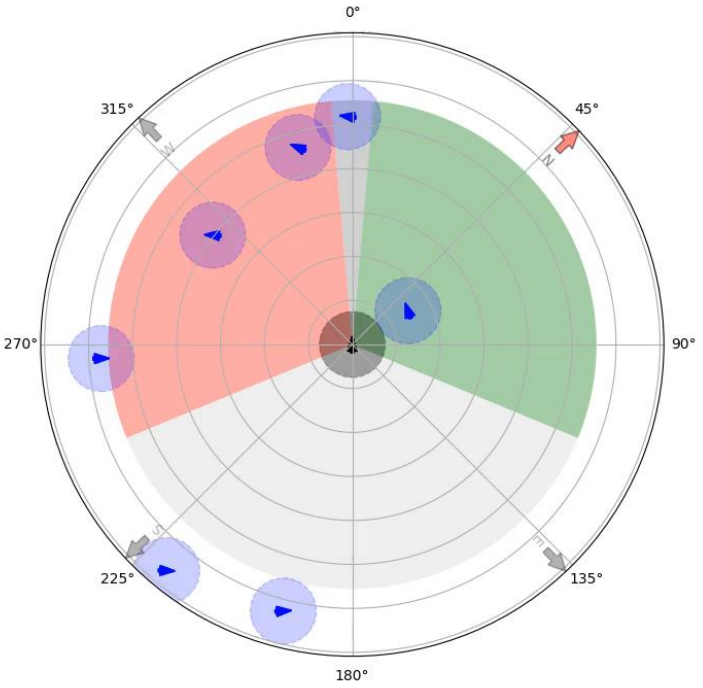




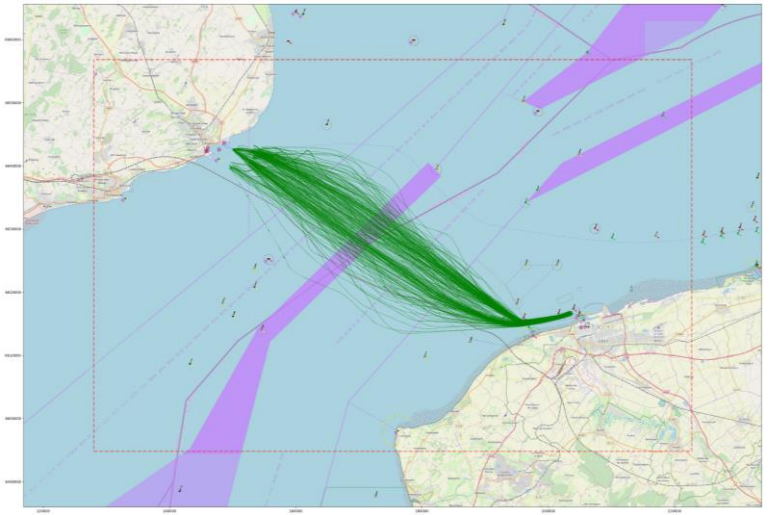
SCENARIO IDENTIFICATION USING AIS DATA

- **Crossing: Give-Way**





DATASET AND DATA PREPARATION



- Dataset
  - Between Dover and Calais
  - Data for one month
  - Harbours were excluded
  - Frequency of the data can reach few minutes
  - Data from different ships is not synchronized

- Data preparation
  - Trajectories filtering
  - Trajectories projection to x-y coordinates
  - Trajectories interpolation to fixed time frame [10 sec]
  - Trajectories synchronization for different ships
  - Trajectories projection to local polar coordinates

AIS message		
Description	Length	Value
Message Type	6	000001
Repeat Indicator	2	00
MMSI	30	001100001111010101000011011110
Navigation Status	4	1111
Rate of turn	8	1000000
Speed over Ground	10	0000000000
Position Accuracy	1	1
Longitude	28	0000001010000101100100000100
Latitude	27	001110101010000010101110110
Course over ground	12	010001010011
True Heading	9	111111111
Time stamp	6	101000
Maneuver indicator	2	00
Spare	3	000
RAIM flag	1	1
Radio status	19	0010100000111110011

SCENARIO IDENTIFICATION

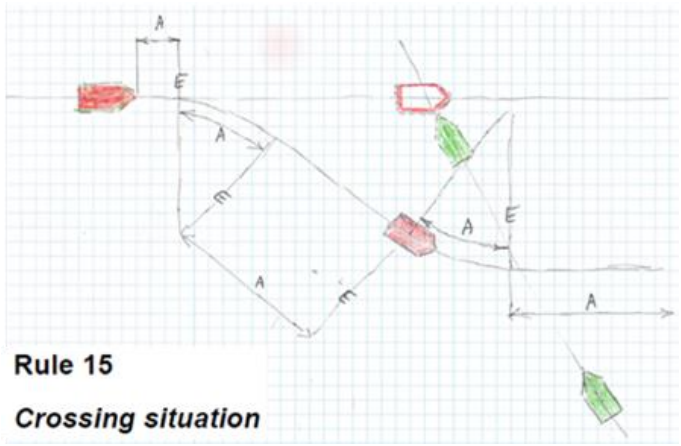
- Assumptions (common practice and literature)
  - Ship Domain: a circle around the ship with radius of 1.5 km (approx. 0.8 NM)*
  - Action Range based on COLERG 11.11 km (approx. 6NM)*
  - Visible Range 13.5km (approx. 7.3 NM)**

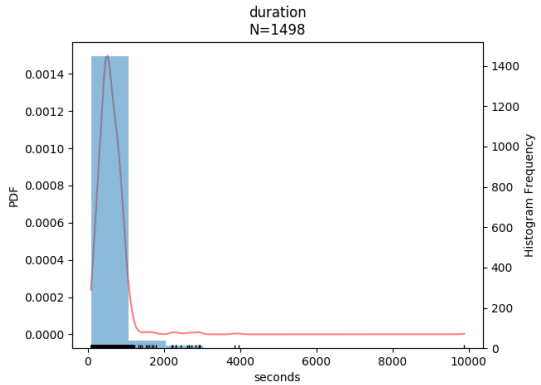
Scenario parameters	
Individual behaviour (ego, targets)	**Interaction between ego and target**
speed on ground (SoG) course on ground (CoG) angle (position)	relative speed relative distance time to closest point of approach (time to collision) distance to closest point of approach (distance to collision) scenario duration

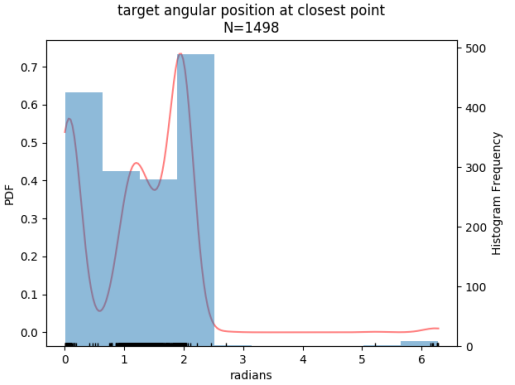
* Zhang et al., 2015
** Lin, 2006

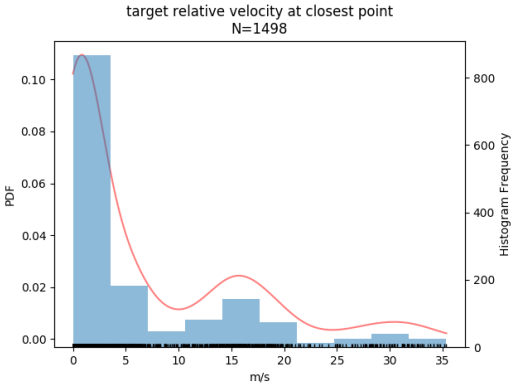
SCENARIO IDENTIFICATION & PARAMETERS DISTRIBUTION

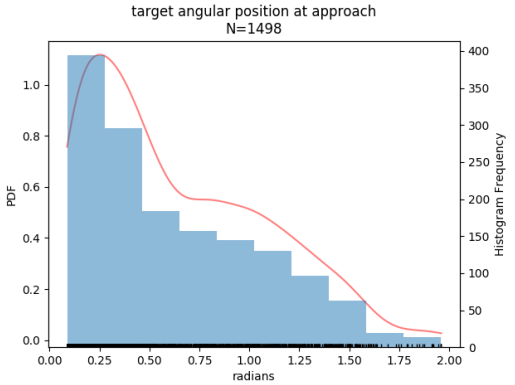
- **Crossing: Give-Way**

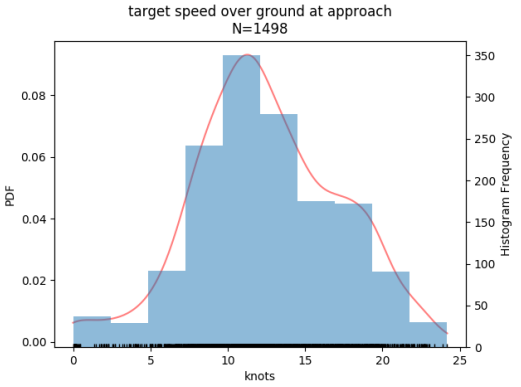


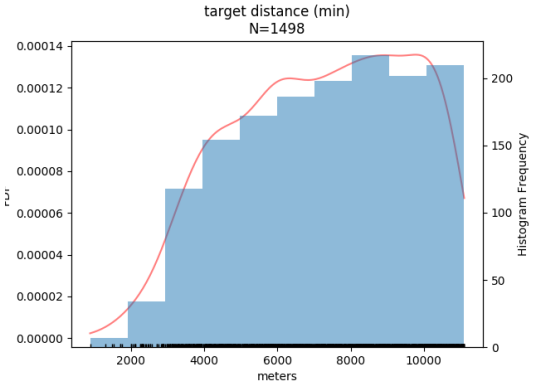


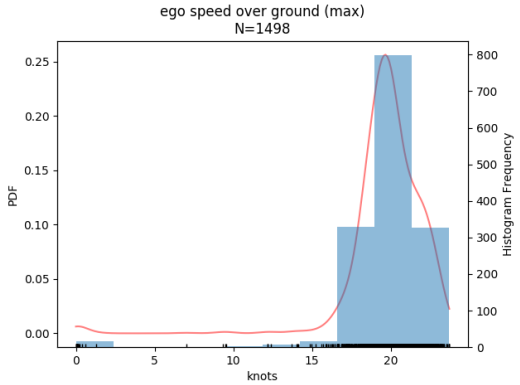


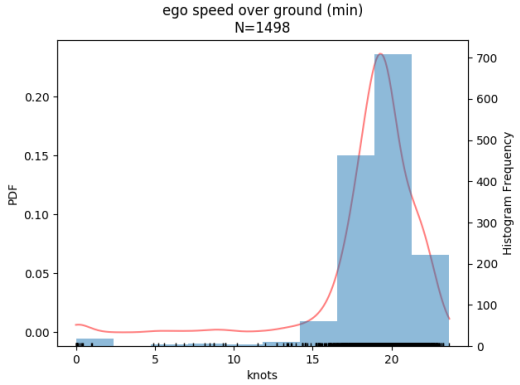


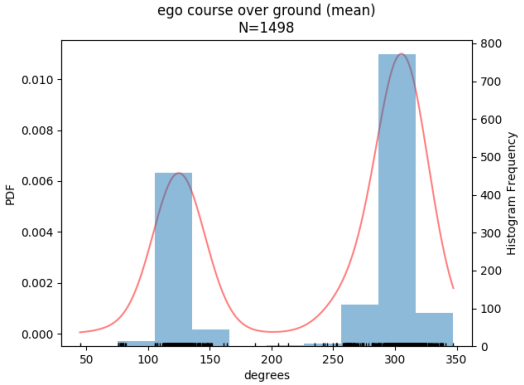












CONCLUSIONS

- It is easily possible to adopt the StreetWise concept and framework by SeaWise
- However there are several challenges to be taken into account

- AIS data showed great potential as rich data source for scenario identification

NEXT STEPS

- Find engaged partners to further develop and enhance the database for SeaWise

- If interested please contact the following:
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  - Eric Engelbrecht – eric.engelbrecht@tno.nl
  - Hala Elrofai – hala.elrofai@tno.nl

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