European Maritime Safety Agency
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Traffic Density Mapping Service

Methodology

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Date: 12.06.2019

EMSA

Document History

Version	Date	Changes	Prepared	Approved
1.0	12/06/2019	Consolidated version. Includes amendments specified during the service implementation	EMSA	

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List of Abbreviations

Abbreviation	Explanation
AIS	Automatic Identification System
DB	Database
EC	European Commission
EMSA	European Maritime Safety Agency
GIS	Geographic Information System
ICT	Information and Communications Technology
IMO	International Maritime Organisation
S-AIS	Satellite AIS
SEG	SSN Ecosystem Graphical interface
SSN	SafeSeaNet
T-AIS	Terrestrial AIS
TDM	Traffic Density Map
TDMS	Traffic Density Mapping Service

List of Definitions

Definition	Explanation
Acquisition time stamp	Time reference information identifying when a certain event occurred.
AIS ship types	The ship type according to UNECE R28. The ship type sorted by the type code enclosed in the AIS-transmitted messages. Part of the ship's static information.
AIS ship type ranges	The ship type groups defined exclusively for the purpose of the TDM (e.g. Cargo, Fishing, Passenger, Tanker, All Other, All Traffic)
Aggregated ship positions	Ship positions data combined from various data sources (e.g. S-AIS and T-AIS).
Colour code/ colour classification	A system of marking objects (e.g. ship routes lines) with different colours as a means of identification.
Down sampling	Process to make a dataset smaller by lowering its sampling rate or sample size.
EMODnet Human Activities portal	Portal presenting information on the intensity and spatial extent of human activities at sea.
Esri Grid format	An ESRI data format for storing raster data that defines geographic space as an array of equally sized square cells arranged in rows and columns.
FTP transfer	The File Transfer Protocol (FTP) is a standard network protocol used for the transfer of files between a client and server.
Georeferenced image	An image where the geographic coordinates are assigned to a raster image in order to define its location.
GIS format	A standard of encoding geographical information into a computer file.
GIS grids	A network of parallel and perpendicular lines superimposed on a map and used for reference.
Line segment	Part of a line that is bounded by two distinct end points (in this case two consecutive ship positions)
Pathways	Ships routes visualised on the traffic density map.
Polyline	A continuous line composed of one or more line segments
PSC ship types	"Type of Ship" information which appears as a ship particular on certain statutory certificates. This information is used to easily verify the definitions and explanations of various ship types.
Raster format	The raster format of the data represents reality by uniform grid cells of a specific resolution. Each square (or grid cell) covers a given geographical area and an attribute value is assigned to the cell.
Raster data files	Spatial data models that define space as an array of equally sized cells. Each cell contains an attribute value and location.
S-AIS	Ships AIS transmissions (messages) detected by satellites.
Ship positions data	Data presenting the ship location at the given time.
Ships identification data	Data identifying the ship: Name; IMO number; MMSI number; Flag.
Ship route	Also – ship track. The actual path of a vessel. Also, the line connecting the object's consecutive positions.
Spatial join	A type of operation in which fields from one layer's attribute table are appended to another layer's attribute table based on the relative locations of the features in the two layers.
T-AIS	Ships AIS transmissions (messages) detected by the shore-based AIS systems.
Traffic Density Mapping Service	The EMSA service provided to visualize the vessel movement patterns for defined maritime geographical areas and time periods.
Vector format maps	A vector-based collection of geographic information system (GIS) data at various levels of detail.
Vessel paths	The actual path of a vessel with respect of the seabed, measured in degrees.

1. Introduction

Traffic Density Maps (TDM) are a simple and effective way of displaying vessel movement patterns, which contribute to a better understanding of maritime traffic. They also help to answer important questions, such as the locations of the main shipping lanes, and which ship types are navigating on which route. The source used to create TDM is historical data of ship positions.

EMSA produced TDM in response to ad-hoc requests to complement specific studies or projects. Following the HLSG mandate given to EMSA for developing a tool to generate TDM, the Agency contacted several Member State Authorities, EU Institutions and research bodies with prior experience in developing TDM, as well as users who expressed their interest in a TDM service. EMSA's analysis demonstrated that it is important to develop a TDM service that allows a dynamic configuration of parameters (e.g. areas, time periods, types of ships) and respects the anonymity of the vessels and their locations.

EMSA could not identify any international standard or method for creating TDM. However, most of the existing methodologies are based on the same approach where the area to be monitored is divided into cells to create a spatial grid. The method selected by EMSA to generate TDM is **the ship routes restoring method**. This method rebuilds the track of each distinct ship from the recorded positions and counts how many routes are crossing each cell of the grid during the selected time period.

This method was chosen because it can be implemented in all regions (coastal and open sea), using all the available ship position data that EMSA holds in its databases. For TDM in EU coastal areas, T-AIS can be used as the main source, while S-AIS can be used in open sea. This method also allows restoring the ship's route within areas with low coverage (see in Figure 1 below):

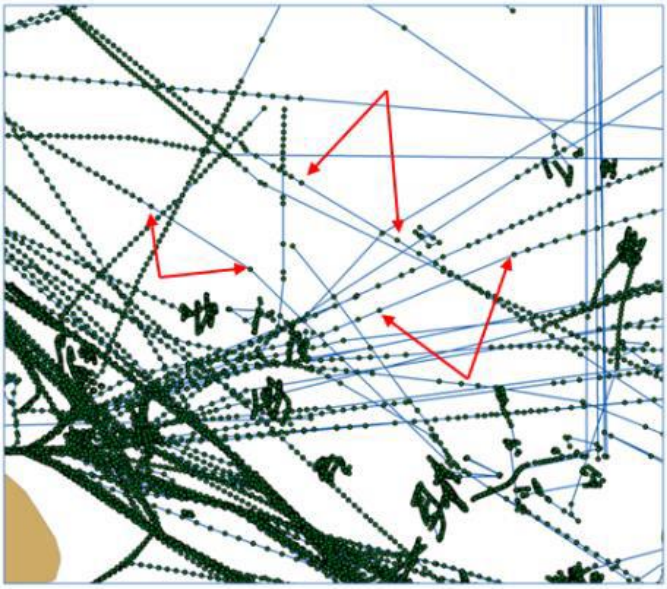


Figure 1: Restoring the ships' routes

The methodology was presented to the Member States at HLSG 3 (28 February 2018) which approved the methodology.

The aim of this document is to present the approved methodology used for calculating the TDM. The document includes also some technical updates and examples showing of the product produced by using the methodology.

2. Methodology for calculating TDM

The following steps are used to calculate a TDM: divide the selected area in cells, aggregate ships positions to create polylines, sort the polylines per ships type ranges, count grid cell crossings, and apply a density classification colouring. The final result is a TDM per ship type range, per area and per the period of time. The steps are presented in Figure 2 below and explained in details hereafter.

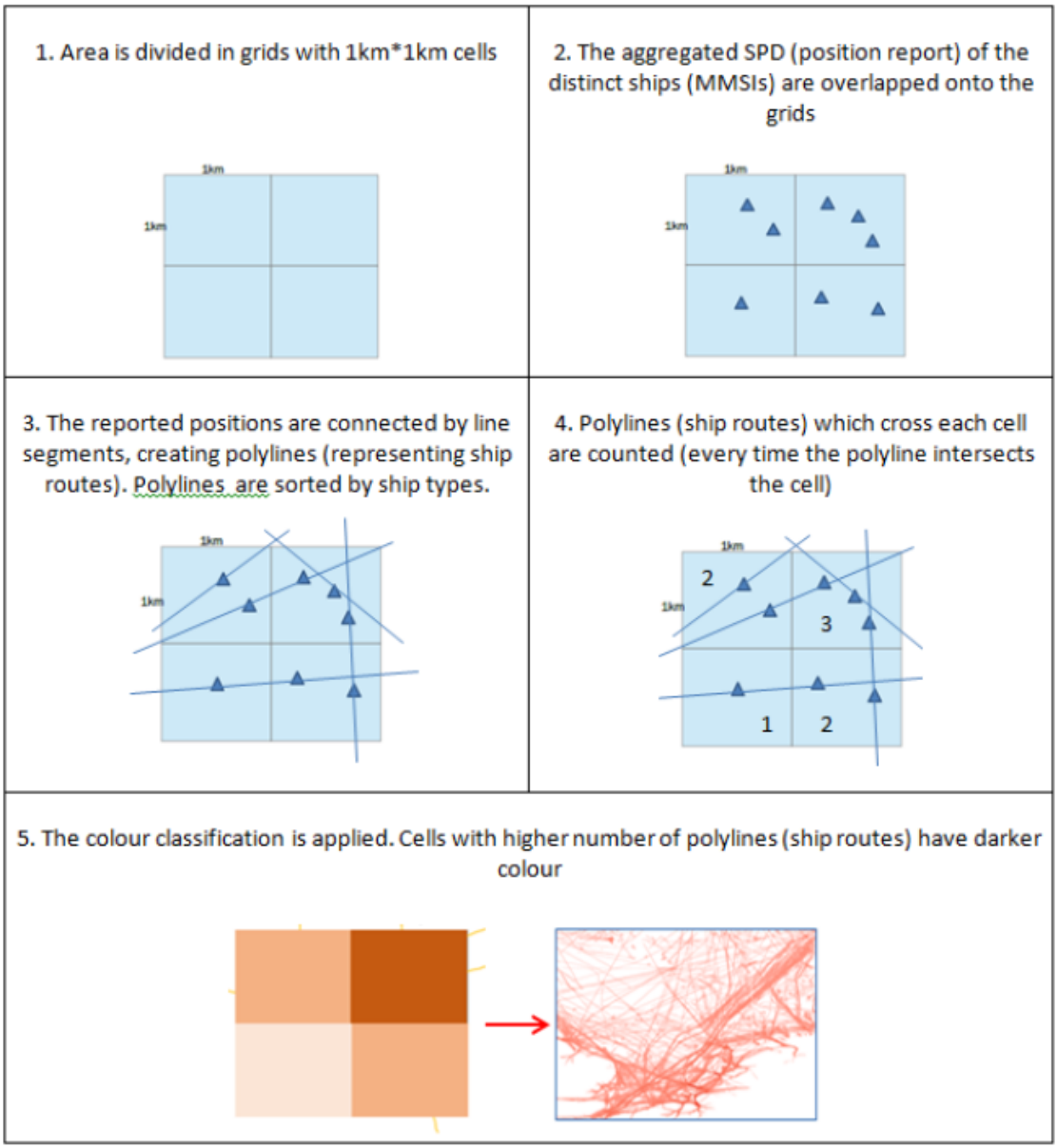


Figure 2: The steps for calculating a TDM

2.1 Preparing ship positions data

2.1.1 Collecting position data

In order to build a TDM, the first step is to collect ship positions data from EMSA's ship position database. Terrestrial AIS (T-AIS) and satellite AIS (S-AIS) data are collected by using an SQL query (filtering). Each ship position is collected with the indication of the ship's type.

The position data is collected and aggregated per period of time and target area. The output of this process is a list of points (ships positions) to create the polyline (ship's route).

2.1.2 Filtering

Positions are checked to remove improbable situations, such as:

- Erroneous positions (e.g. longitude or latitude equal to exactly 0).
- Duplicated positions (e.g. timestamp and remaining information is exactly the same).

2.1.3 Down-sampling

Position data with a high frequency acquisition (e.g. T- AIS data) is down-sampled (e.g. one position per 6 minutes) per ship (MMSI). S-AIS data is not down-sampled. The down-sampling rate is configurable.

2.1.4 Recreating ships routes

This step is required to link the consecutive vessel's positions in a chronological order. The collected position reports of each ship (MMSI) are selected.

Figure 3: Individual position reports

The routes are recreated by connecting the position reports into polylines using the acquisition time stamp to order the points. The output of this process is a file containing the route polylines (e.g. as a shapefile) per MMSI for a configurable period of time.

Figure 4: Polylines

The polylines are then tagged per AIS ship types ranges. The result is a file with the ship route and ship type information.

2.1.5 Lines filtering

This step removes the polyline segments which are obviously improbable, such as:

- Polyline segments joining two consecutive positions of the same vessel (MMSI) too distant in time from each other (e.g. 4 hours),
- Too long polyline segments joining two consecutive positions of the same vessel (e.g. >100 NM),
- Too short polyline segments joining two consecutive positions of the same vessel (e.g. <10m.),
- Polyline segments overlapping land area (either by checking if the polyline goes beyond existing grid cells or it crosses a land polygon).

The filtering settings are configurable.

2.2 TDM construction

The density map is created by counting the number of routes (polylines) crossing each cell and applying a colour code corresponding to the number of crossings. The process to create a map can be divided into the following steps:

2.2.1 Selecting grid cells

The area is divided into a number of grid cells. The grids used as reference to build the TDM are constructed to cover all the target areas and have a definition of 1x1 km. They follow the INSPIRE data specifications on Geographical Grid systems described in: https://inspire.ec.europa.eu/id/document/tg/gg

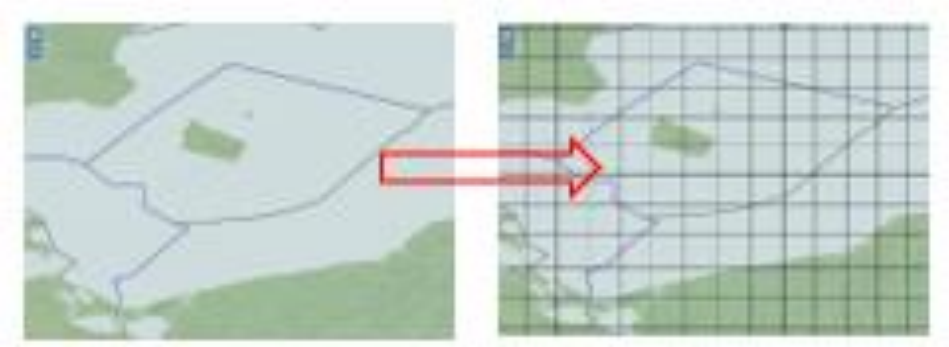


Figure 5: The area is divided into cells

2.2.2 Selecting routes (polylines)

The ship routes (created polylines) are selected inside each of the cells.

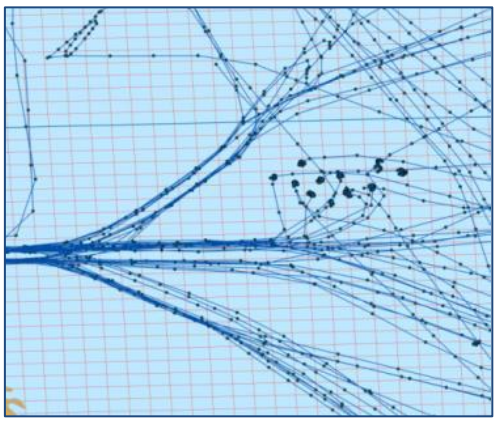


Figure 6: Ship positions connected by lines

2.2.3 Count and sum

The system counts the number of polylines crossing each cell.

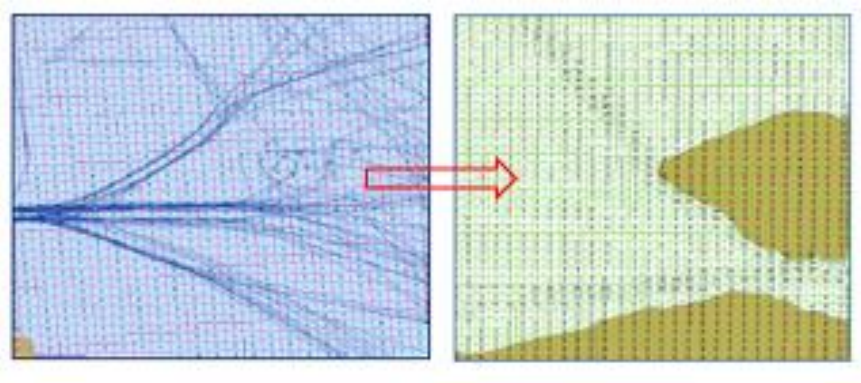


Figure 7: Counting the number of polylines crossing each cell

For each cell of the TDM grid (1x1 km) the number of lines crossing the cell boundary (entering / exiting) is counted.

The output of this process is a grid data file containing the number of vessel route crossings per cell. The files are created for all combinations of the predefined criteria (i.e. area, ship type range and time period).

2.2.4 Calculating the traffic density

The traffic density (the number of polylines crossing each cell) is presented by using a colour code. Depending on the number of crossings detected, a colour code is given to each cell. The number of the colour classes can be chosen depending on the TDM details to be presented.

Figure 8: Colour ramp

The colour classification process is presented in Figure 9.

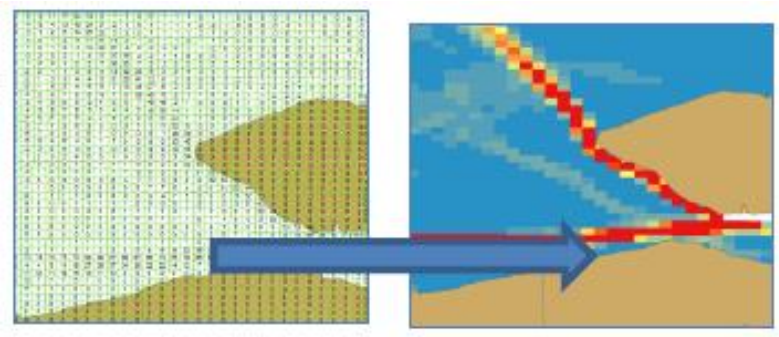


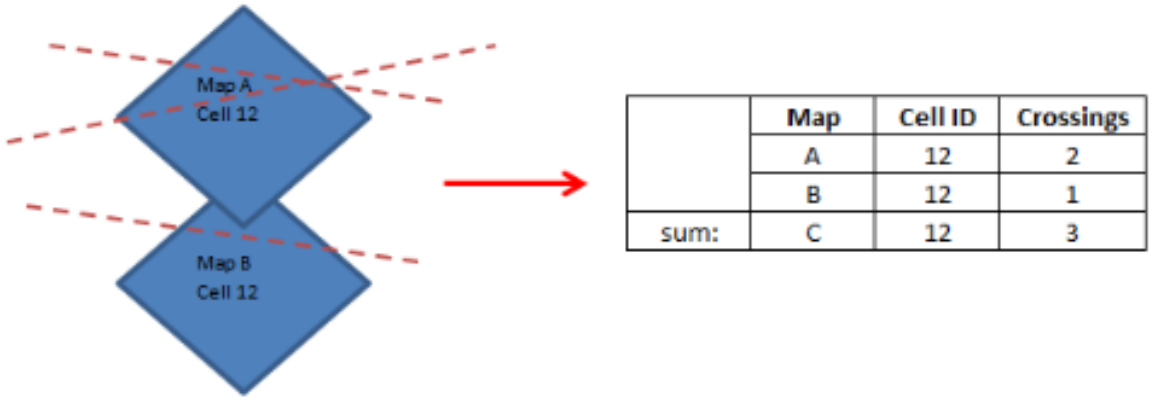
Figure 9: Colour classification

The output of this process is a georeferenced image file showing a density map with a predefined colour code by cells. The files are created for all combinations of the predefined criteria (i.e. area, ship type range and time period).

2.3 Combining TDMs

Once a set of basic maps (grid data files) have been created, they can be combined (using the sum function), to create new maps. This allows us to avoid re-treatment of the data.

For example, the basic maps are produced on a monthly basis. A seasonal map can be created by combining the same grid data files of 3 months.



	Map	Cell ID	Crossings
	A	12	2
	B	12	1
sum:	C	12	3

Figure 10: Combining TDMs

TDMs are stored in a raster format for later retrieval and use.

2.4 Reference data

2.4.1 Areas

TDMs are calculated for the following predefined areas:

- North Sea/North Atlantic;
- Atlantic;
- Mediterranean Sea;
- Black Sea;
- Baltic Sea;
- All Europe.

The list of predefined areas is available in Annex A. The limits of areas are specified by shapefiles.

2.4.2 Time criteria

The time categories for TDM calculations are:

- Month - presents the data collected during a calendar month, from the 1st date till the last date of the corresponding month).
- Season - present the data collected during the following periods:
  - Spring (period: March, April, May);
  - Summer (period: June, July, August);
  - Autumn (period: September, October, November);
  - Winter (period: December, January, February);
- Year - present the data collected during a calendar year.

The basic period for the TDM is one month. All calculations are provided for the previous reference period.

2.4.3 Ship type ranges

The following ship type ranges are considered:

- Passenger;

- Cargo;
- Tanker;
- Fishing;
- All Other (i.e. all ship types not listed in the above bullet points);
- All Traffic (i.e. all ships monitored).

The ship type ranges mapping table is available in Annex B.

2.4.4 TDMs dataset

The final TDMs are produced by aggregating (stacking and summing) the intermediate files generated according to the configured time criteria (i.e. monthly, seasonal and annual maps) and ship type ranges (i.e. Cargo, Fishing, Passenger, Tanker, All Other and All traffic) and finally clipping according to the preconfigured geographic areas (Mediterranean Sea, Baltic Sea, etc.)

For each individual TDM, the following files are produced:

- A georeferenced image showing a density map with a predefined colour code by cell (e.g. a GeoTiff file);
- A grid data file containing the number of vessels routes crossings per cell (e.g. GeoTiff 16 bit signed) (Value - 9999 is assigned for cells without data);
- A metadata file, which provides the following information about the TDM:
  - Creation date and time,
  - Area covered,
  - Ship type range covered,
  - Time category of TDM,
  - Start date,
  - End date,
  - Number of vessels,
  - Number of vessels per ship type range (only for the TDMs combining all monitored ship types),
  - Comment (if required), and/or
  - Colour legend (value ranges and corresponding colour codes).

Annex C presents some examples of TDMs produced using the methodology and visualised via SEG.

2.5 Process

The overall process for calculating TDM, as presented above, can be summarised in the following process diagram:

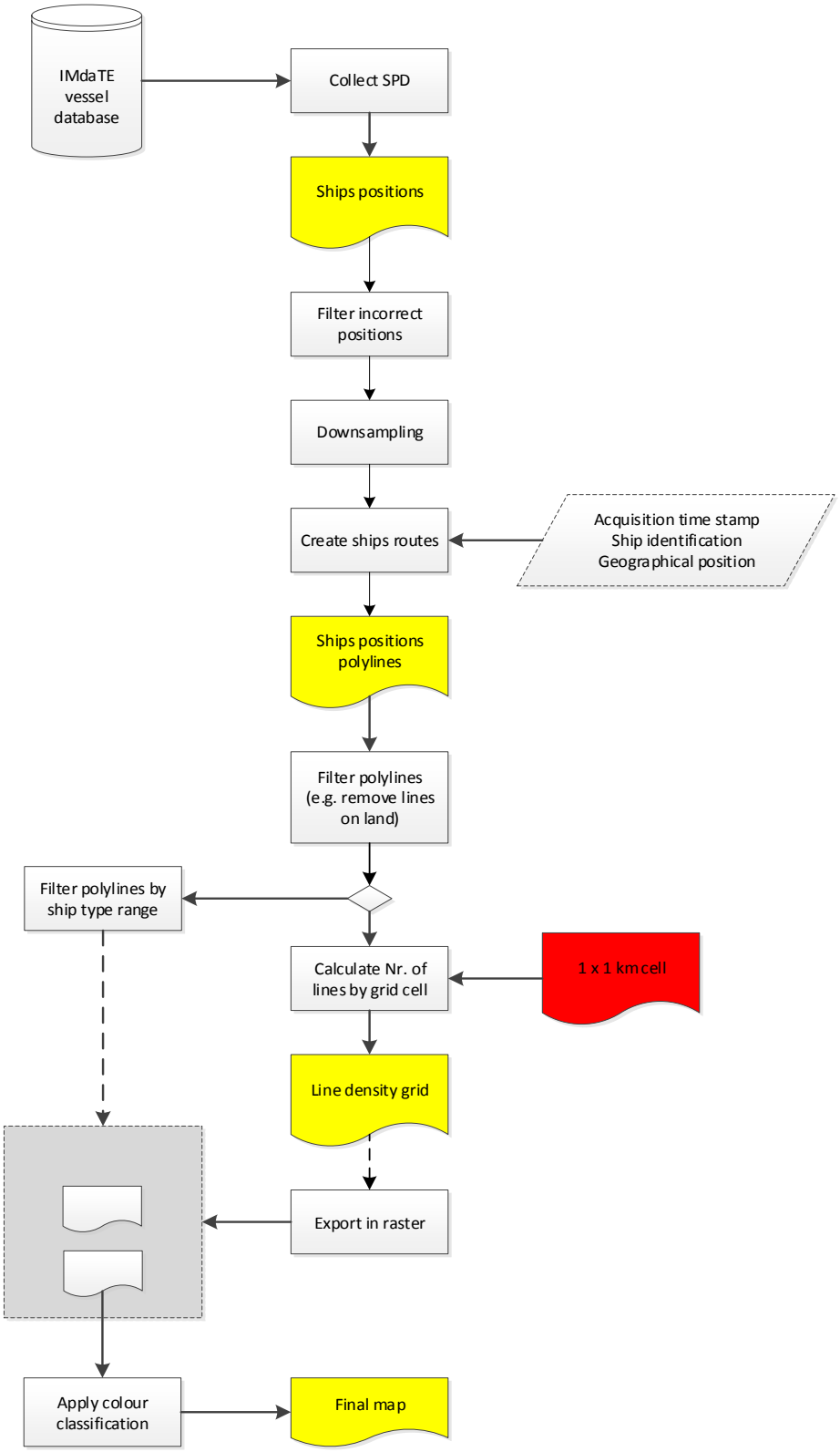


Figure 11: The process for calculating a TDM

Annex A: Areas

Each TDM corresponds to one of the reference areas:

- North Sea/North Atlantic;
- Atlantic;
- Baltic Sea
- Black Sea;
- Mediterranean Sea;
- All Europe.

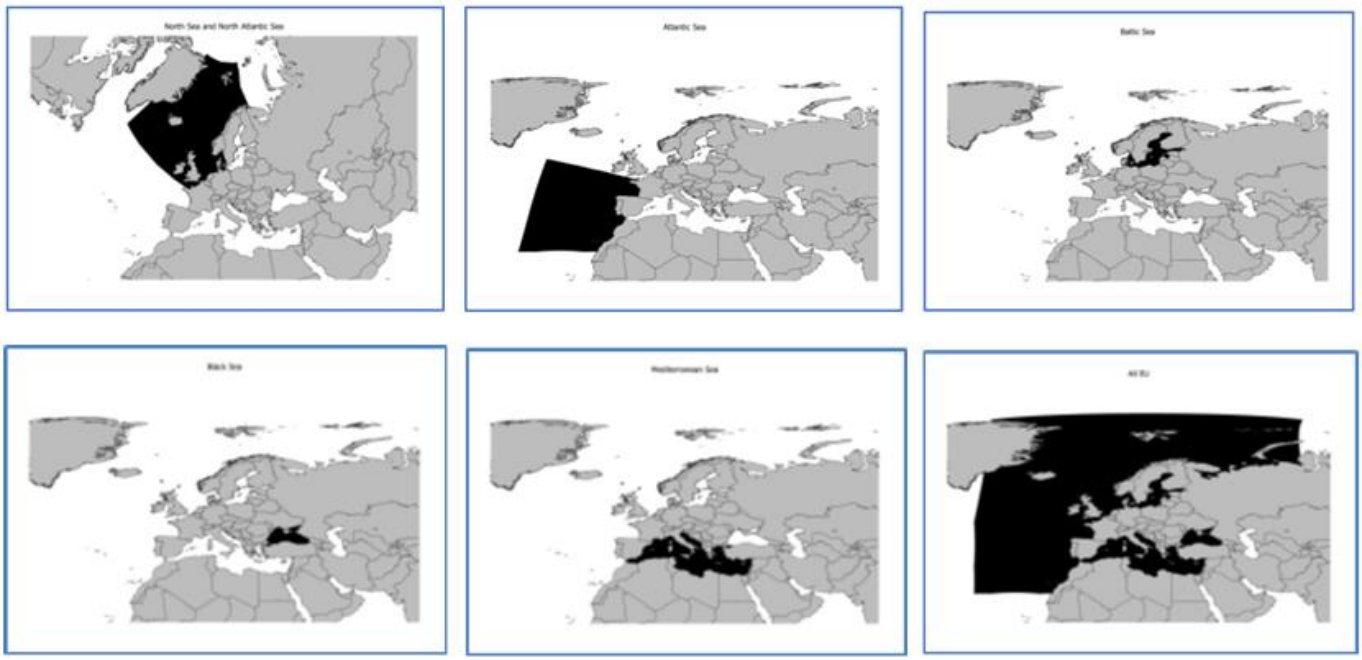


Figure 12: TDMS areas (1)

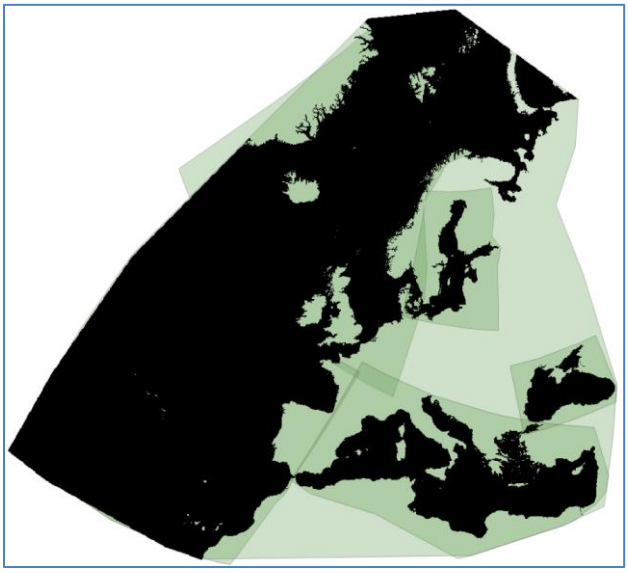


Figure 13: TDMS areas (2)

The limits of areas are specified by shapefiles.

Annex B: Ship type ranges

The system will consider the following ranges of ship types: Passenger, Cargo, Tanker, Fishing, All Other[1] and All Traffic[2].

Ship types (AIS and PSC) are sorted per the above ship type ranges. The matching table between ship types and the ship type ranges is presented below.

CODE (AIS/ PSC)	TYPE	RANGES	
0	Not specified	All Other	All Traffic
1-19	Reserved for future use	All Other	All Traffic
20	Wing in ground (WIG), all ships of this type	All Other	All Traffic
21	Wing in ground (WIG), Hazardous category A	All Other	All Traffic
22	Wing in ground (WIG), Hazardous category B	All Other	All Traffic
23	Wing in ground (WIG), Hazardous category C	All Other	All Traffic
24	Wing in ground (WIG), Hazardous category D	All Other	All Traffic
25	Wing in ground (WIG), Reserved for future use	All Other	All Traffic
26	Wing in ground (WIG), Reserved for future use	All Other	All Traffic
27	Wing in ground (WIG), Reserved for future use	All Other	All Traffic
28	Wing in ground (WIG), Reserved for future use	All Other	All Traffic
29	Wing in ground (WIG), Reserved for future use	All Other	All Traffic
30	Fishing	Fishing	All Traffic
31	Towing	All Other	All Traffic
32	Towing: length exceeds 200m or breadth exceeds 25m	All Other	All Traffic
33	Dredging or underwater ops	All Other	All Traffic
34	Diving ops	All Other	All Traffic
35	Military Ops	All Other	All Traffic
36	Sailing	All Other	All Traffic
37	Pleasure Craft	All Other	All Traffic
38	Reserved	All Other	All Traffic
39	Reserved	All Other	All Traffic
40	High speed craft (HSC), all ships of this type	All Other	All Traffic
41	High speed craft (HSC), Hazardous category A	All Other	All Traffic
42	High speed craft (HSC), Hazardous category B	All Other	All Traffic
43	High speed craft (HSC), Hazardous category C	All Other	All Traffic
44	High speed craft (HSC), Hazardous category D	All Other	All Traffic
45	High speed craft (HSC), Reserved for future use	All Other	All Traffic
46	High speed craft (HSC), Reserved for future use	All Other	All Traffic
47	High speed craft (HSC), Reserved for future use	All Other	All Traffic
48	High speed craft (HSC), Reserved for future use	All Other	All Traffic
49	High speed craft (HSC), No additional information	All Other	All Traffic
50	Pilot Vessel	All Other	All Traffic
51	Search and Rescue vessel	All Other	All Traffic
52	Tug	All Other	All Traffic
53	Port Tender	All Other	All Traffic
54	Anti-pollution equipment	All Other	All Traffic

[1] "All other" is the combination of relevant ship types. This combination is considered for the TDMS purposes only.
[2] "All traffic" is the combination of all the monitored ship types. This combination is considered for the TDMS purposes only.

55	Law Enforcement	All Other	All Traffic
56	Spare - Local Vessel	All Other	All Traffic
57	Spare - Local Vessel	All Other	All Traffic
58	Medical Transport	All Other	All Traffic
59	Ship according to RR Resolution No. 18	All Other	All Traffic
60	Passenger, all ships of this type	Passenger	All Traffic
61	Passenger, Hazardous category A	Passenger	All Traffic
62	Passenger, Hazardous category B	Passenger	All Traffic
63	Passenger, Hazardous category C	Passenger	All Traffic
64	Passenger, Hazardous category D	Passenger	All Traffic
65	Passenger, Reserved for future use	Passenger	All Traffic
66	Passenger, Reserved for future use	Passenger	All Traffic
67	Passenger, Reserved for future use	Passenger	All Traffic
68	Passenger, Reserved for future use	Passenger	All Traffic
69	Passenger, No additional information	Passenger	All Traffic
70	Cargo, all ships of this type	Cargo	All Traffic
71	Cargo, Hazardous category A	Cargo	All Traffic
72	Cargo, Hazardous category B	Cargo	All Traffic
73	Cargo, Hazardous category C	Cargo	All Traffic
74	Cargo, Hazardous category D	Cargo	All Traffic
75	Cargo, Reserved for future use	Cargo	All Traffic
76	Cargo, Reserved for future use	Cargo	All Traffic
77	Cargo, Reserved for future use	Cargo	All Traffic
78	Cargo, Reserved for future use	Cargo	All Traffic
79	Cargo, No additional information	Cargo	All Traffic
80	Tanker, all ships of this type	Tanker	All Traffic
81	Tanker, Hazardous category A	Tanker	All Traffic
82	Tanker, Hazardous category B	Tanker	All Traffic
83	Tanker, Hazardous category C	Tanker	All Traffic
84	Tanker, Hazardous category D	Tanker	All Traffic
85	Tanker, Reserved for future use	Tanker	All Traffic
86	Tanker, Reserved for future use	Tanker	All Traffic
87	Tanker, Reserved for future use	Tanker	All Traffic
88	Tanker, Reserved for future use	Tanker	All Traffic
89	Tanker, No additional information	Tanker	All Traffic
90	Other Type, all ships of this type	All Other	All Traffic
91	Other Type, Hazardous category A	All Other	All Traffic
92	Other Type, Hazardous category B	All Other	All Traffic
93	Other Type, Hazardous category C	All Other	All Traffic
94	Other Type, Hazardous category D	All Other	All Traffic
95	Other Type, Reserved for future use	All Other	All Traffic
96	Other Type, Reserved for future use	All Other	All Traffic
97	Other Type, Reserved for future use	All Other	All Traffic
98	Other Type, Reserved for future use	All Other	All Traffic
99	Other Type, No additional information	All Other	All Traffic
310	Tankship + cc	Tanker	All Traffic

311	NLS tanker	Tanker	All Traffic
312	Combination carrier	Tanker	All Traffic
313	Oil tanker	Tanker	All Traffic
314	Vegetank	Tanker	All Traffic
315	Fishing vessel	Fishing	All Traffic
316	Warship and naval auxiliary	All Other	All Traffic
317	Wooden ship of a primitive build	All Other	All Traffic
318	Government ship used for non-commercial purpose	All Other	All Traffic
319	Pleasure yacht not engaged in trade	All Other	All Traffic
320	Gas carrier	Tanker	All Traffic
321	Gas carrier LPG	Tanker	All Traffic
322	Gas carrier ING	Tanker	All Traffic
330	Chemical tanker	Tanker	All Traffic
340	Bulk carrier	Cargo	All Traffic
341	Cement carrier	Cargo	All Traffic
350	Unit. vessel	All Other	All Traffic
351	Barge carrier	Cargo	All Traffic
352	Vehicle carrier	Cargo	All Traffic
353	Container	Cargo	All Traffic
354	Pallet carrier	Cargo	All Traffic
355	Ro-Ro cargo	Cargo	All Traffic
360	General cargo/multipurpose	Cargo	All Traffic
361	Refrigerated cargo	Cargo	All Traffic
367	Livestock carrier	Cargo	All Traffic
370	Ro-Ro passenger ship	Passenger	All Traffic
371	Passenger ship	Passenger	All Traffic
372	Ice breaker	All Other	All Traffic
373	Fish factory	All Other	All Traffic
374	Research ship	All Other	All Traffic
375	Heavy load	All Other	All Traffic
376	Offshore supply	All Other	All Traffic
377	Standby ship	All Other	All Traffic
378	Dredger	All Other	All Traffic
380	MODU & FPSO	All Other	All Traffic
381	Dyncraft	All Other	All Traffic
382	Special purpose ship	All Other	All Traffic
383	High speed passenger craft	All Other	All Traffic
384	High speed cargo	All Other	All Traffic
385	Tug	All Other	All Traffic
399	Other special activities	All Other	All Traffic

Note: in case the ship type code has an empty value (not filled in) or the value is not listed in the table, it shall be considered as range: "All Other" and "All Traffic"

Annex C: Examples

Examples of TDM in SEG are presented below:

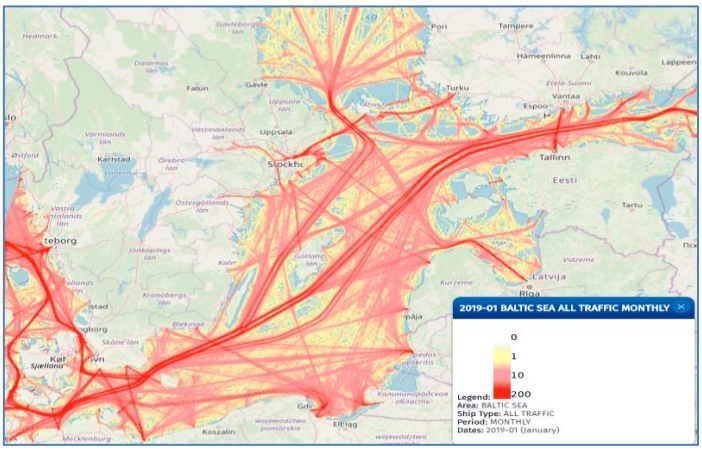


Figure 14: TDM (area – Baltic Sea; time criteria – monthly TDM; ship type range – All traffic)

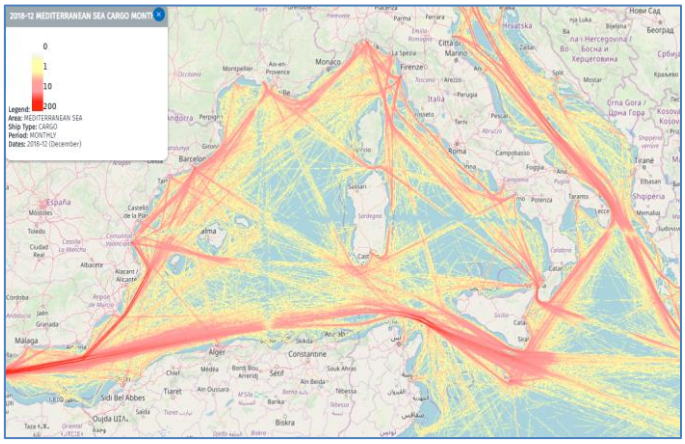


Figure 15: TDM (area – Mediterranean Sea; time criteria – monthly TDM; ship type range – Cargo)

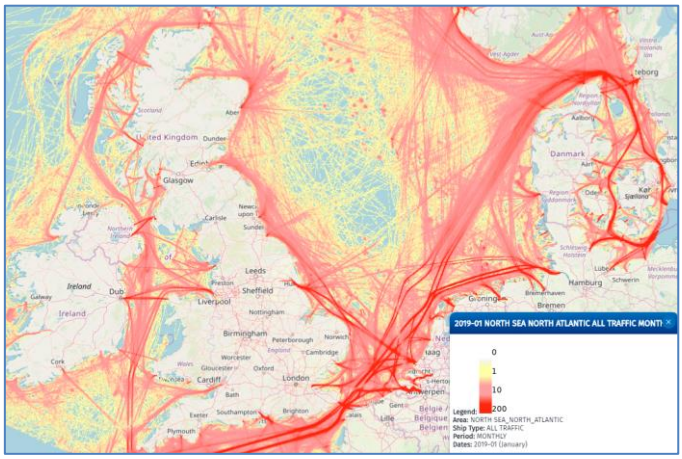


Figure 16: TDM (sample area – North Sea /Atlantic; time criteria – monthly TDM; ship type range – All traffic)

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