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METEOROLOGICAL NAVIGATION AND ECDIS

ABSTRACT

In maritime traffic, a route is one or more known tracks along which navigation takes place or there is intention to sail. Meteorological factors are important if the route exceeds the distance of 1500M [1]. Meteorological navigation is the selection of a navigational route in view of meteorological factors and control of vessel during heavy weather conditions and safe navigation aimed at the protection of human lives, vessels and cargo during heavy weather. The paper proposes a model of grouping and evaluating estimates of meteorological factors when planning meteorological navigation. It is advised to upgrade the Electronic Chart Display and Information System – ECDIS program with the aim of allowing for the computer planning of meteorological navigation.

KEY WORDS

planning of navigation, meteorology, optimal route, Electronic Chart Display and Information System - ECDIS

1. INTRODUCTION

In maritime traffic, a route is one or more known tracks along which navigation takes place or there is intention to navigate. A route of known length is determined by planning of the voyage. It includes all major navigation factors like: safety, time of departure and arrival to the port, etc. The route is selected by the navigational officer and approved by the captain of the ship. In maritime traffic time is an important factor in vessel efficiency. The objective to save time and money is often contrary to professional rules about a safe voyage. When selecting the route it is necessary to take into account that the shortest route is not necessarily the safest one.

Meteorological factors are increasingly important if the route exceeds 1500M [1]. Meteorological navigation is the selection of navigational route in view of meteorological factors and control of the vessel during heavy weather conditions and safe navigation aimed at the protection of human lives, ship and cargo in heavy weather.

In this paper, the authors propose a model of grouping and evaluating estimates of meteorological factors when planning meteorological navigation. It is advised to upgrade the *Electronic Chart Display and Information System* program – ECDIS with the aim of allowing for computer planning of meteorological navigation [2].

It is expected that such application will facilitate the selection of the route in meteorological navigation for the navigation officer.

2. METEOROLOGICAL FACTORS

Meteorological factors can be assessed on the basis of meteorological data. They are found in *Maritime Safety Information – MSI* [3]. Maritime safety information relating to meteorology at sea are collected through measurements and surveys obtained by:

1) meteorological satellites,
2) land meteorological stations, and
3) vessel meteorological stations [4].

Recordings of meteorological satellites showing air masses and surveillance of other factors in the atmosphere are considered as basic measurements. The

results of the measurements are forwarded to land stations and others.

Land meteorological stations are located at various land positions. They measure atmospheric meteorological data from the land and collect satellite data and vessel meteorological data for the purpose of producing weather forecasts.

Vessel meteorological stations are parts of *Voluntary Observing Ship* (*VOS*). Ships and offshore objects are equipped with adequate technical and technological equipment. By means of *VOS* maximally accurate data about an area are gathered.

Gathered, analysed and adapted meteorological data are distributed in the form of maritime safety information through:

1) satellite-, and
2) terrestrial communication systems.

The International Maritime Satellite – INMARSAT system is used for distributing maritime safety information with meteorological data via satellite in maritime traffic [5].

Terrestrial communication systems contain standardised procedures for distributing maritime safety information with meteorological data using *VHF*, *MF* and *HF* communication networks.

3. PLANNING OF VOYAGE, METEOROLOGICAL NAVIGATION AND ROUTES

Planning of a voyage refers to all activities related to the creation of the voyage plan. These activities include gathering and analysing available data. The data are gathered from nautical charts, publications, communication devices, navigational equipment and data about the vessel.

In meteorological navigation, the most convenient route is selected taking into consideration the meteorological factors and control of the vessel in heavy weather.

The route is planned before the voyage and adjusted during the voyage. Transatlantic navigation can be:

1) orthodrome navigation,
2) loxodrome navigation, and
3) combined navigation.

In orthodrome navigation the vessel often enters the high latitude zones. In terms of safety of navigation those areas are considered as meteorologically and oceanologically unfavourable. There, the vessels sail close to border areas of glaciers. The sea is rough throughout the year and the winds are strong and cold.

When sailing along the loxodrome the frequent change of the course can be avoided, but the length of the route is increased. Greater distance does not necessarily mean a longer voyage.

In combined navigation, loxodrome and orthodrome navigations are combined. High latitudes of northern hemisphere and low latitudes of southern hemisphere are avoided.

From the aspect of meteorological and oceanological factors the selection of the route is also affected by the current situation of the vessel and the prediction of future factors. The planned route is checked for a particular season in pilot charts which contain air and sea currents, limits of sea ice etc. The safety aspects are determined by studying the sea charts, navigational publications and maritime safety information.

In order to make decisions in compliance to valid conditions the following factors are analysed:

1) external factors, and
2) vessel factors.

External factors are:

1) current geographic position,
2) position of the destination,
3) distance to the destination,
4) length of the voyage,
5) presence of ice,
6) tides,
7) water level (when sailing along rivers),
8) state of the sea,
9) visibility,
10) temperature,
11) weather forecast,
12) sea and water currents,
13) safety of navigation, and
14) others.

The current geographic position is the reached position, i.e. the position from which it is necessary to plan the meteorological navigation. It is expressed by geographic coordinates (λ and φ).

The position of the destination is the geographic position of the destination described by the coordinates (λ and φ).

The distance to the destination is determined by the remaining part of the route measured from the current geographic position of the vessel to the geographic position of the destination expressed in nautical miles (*M*). The distance to the destination is an inconsistent variable. It changes according to the divergence of the real route from the planned route.

The duration of the voyage is the time spent in the voyage from the beginning of the voyage to the end of the voyage. It depends on the speed of the vessel, the length of the navigational route and meteorological factors during the voyage. In case of meteorological navigation, it is the time from the current geographical position of the vessel to the geographical position of the destination. It is expressed in days (*D*), hours (*h*) and minutes (*min.*).

The presence of ice is a dangerous occurrence at sea, especially in the areas where it is not expected. Glaciers may travel under the influence of currents and

reach beyond the ice zones. In some areas the ice may restrict or even completely obstruct the navigation. Travelling of glaciers and the extension of ice zones has been described in publications and special charts. The presence of ice on the deck may jeopardise the vessel's stability. The probability of occurrence of ice is taken on the basis of statistical data of observance of the occurrence during several years and the existing currents.

Tides are a factor that may restrict the navigation in some areas because of decrease of depth. The unit for the lowest and he highest values (high and low tide) is expressed in metres (*m*) and is calculated by means of *Tide table*s. Tides are important for the draft of the vessel.

In river navigation water level denotes the current level of water of a river, lake or channel. It is expressed in metres (*m*). It depends on sea tides, precipitations, wind etc. The data about water level are obtained by means of communication devices. Water level is important for the draft of the vessel.

The state of the sea is described by the direction, size and frequency of the waves. The direction of the waves is considered from the aspect of which side of the world they come from. The size of the waves is measured from the hollow to the crest of the wave. The frequency of the waves is measured by the number of waves in a unit length. The state of the sea is described in the Baufort, Douglas or Petersen scale for the state of the sea. The waves may significantly prolong or shorten the time of the voyage. The data about the state of the sea are received through communication devices. The estimation about the current state is done by observing the sea [6].

The visibility is determined by the distance of visibility of distant objects on the horizon. The measure for visibility is determined by the distance of the range of sight. The distance of the range of sight is expressed in kilometres (*km*). It is important for the safety of navigation especially in the areas of higher intensity of traffic or the need for manoeuvrings (narrow straits, channels, rivers, lakes etc.). The data about visibility are obtained on the basis of weather forecasts via communication devices. The current visibility data are obtained by observing the horizon and on the basis of evaluating the meteorological factors (air and water temperature, pressure, wind, etc.) [6]. Information on visibility is important for the planning of the optimal meteorological route (*OMR*) for the areas with higher traffic intensity.

The air temperature is the level of air heat. The water temperature is the level of the water heat. It is measured by a mercury thermometer and the measuring unit is Celsius grade (°C). *Maritime Safety Information – MSI* relating to temperature is obtained through measurements on the vessel or through communication devices (*INMARSAT, NAVTEX, VHF* etc.) [7]. The temperature of the air and sea and the atmospheric pressure do not have significant effects on the navigation, but they are considered in weather forecasting. Hence, temperature has to be taken into account when planning the optimal meteorological route.

Weather forecast refers to forecasting meteorological phenomena (wind, waves, temperature and precipitations). They are obtained by observing the motions of pressure, clouds and wind and by reading synoptic charts. Weather forecasts are available through communication devices (*INMARSAT, NAVTEX, Weather facsimile* etc.) while synoptic charts are available by Weather facsimile. Weather forecast is produced for a six-hour unit [7].

Sea and water streams are currents which occur because of the motion of water masses. They are held important in planning the optimal meteorological route as they may significantly affect the speed of the vessel. They are measured in knots. The data about sea currents may be found in nautical charts and publications.

The state of the wind is determined by its direction and force. The direction of the wind is the direction from which it blows. The force of the wind is determined by its speed and is measured in knots (*M/h*) and metres per second (*m/*s). The state of the wind is given in Beaufort wind scale. Precipitations (weather) are described in the scale, relating to the cloudiness and precipitations. Precipitations may restrict visibility and cause interference in the ship's radar. Such phenomena are inconvenient for the areas of high density of traffic and affect the safety of navigation [7].

The safety of navigation is a set of regulations, rules, standards and customs which regulate navigation in order to reduce the hazard of losses of human lives and property. The factors that are related to the safety of navigation are affected by:

1) navigational route recommended in marine charts or nautical manuals,
2) areas of separate navigation,
3) customary navigational routes recommended by the institutions for meteorological control of vessels,
4) position and size of the area prohibited for navigation,
5) position and area of navigation permitted by the "International Convention on Load Lines", and
6) available navigational systems in the navigational area.

Factors of the vessel are:

1) characteristics of the vessel,
2) autonomy of the vessel's navigation,
3) safety of the vessel,
4) requirements of the ship operator, freighter and insurer,
5) specific characteristics of cargo,

6) position of special areas and particularly sensitive areas, and
7) others.

The characteristics of the vessel are determined by technical characteristics of the ship. Technical characteristics describe the vessel's dimensions, power and speed. The vessel's dimensions are determined by its length, width, height and draft. The power of the vessel is determined by its purpose (passenger, cargo, tug, icebreaker, fishing boat etc.). The speed of the vessel is determined by the power of the propulsion and by the form of the vessel.

The autonomy of the vessel is the time of the stay of the vessel at sea with current supplies. Current supplies refer to the reserves of fuel, oil, potable water, food, spare parts and other supplies. The autonomy of the vessel is an inconstant variable and is taken on the basis of current available data about the supplies in relation to the current and expected consumption.

The safety equipment of the vessel is the level of equipment of the vessel for the safe navigation along a particular area. Safety navigation refers to all navigational and communication equipment, search and rescue equipment etc. Limitations of the vessel are determined by the shipping registry in conformity with international rules and standards. Restrictions are specified for the distance from the coast, for particular seas, areas, etc. [8] [9] [10].

The requirements of the ship operator, freighter and insurer are their special requirements relating to the use of a particular navigational route. Such requirements are related to business operations of the company and the ship, and should not influence the

Table 1 - External factors in meteorological navigation

MARK: A		
External Factors in Meteorological Navigation		
Influential Factor Mark	Meaning	Measuring Unit or Source
a_1	Current geographic position	λ , φ
a_2	Destination	λ , φ
a_3	Distance to destination	M
a_4	Length of the voyage	D, h, min.
a_5	Ice	Weather forecast or meteorological measurements
a_6	Sea tides	Marine charts and navigational publications
a_7	Water level when navigating along rivers	m
a_8	State of the sea	Weather forecast or meteorological measurements
a_9	Visibility	Weather forecast or meteorological measurements
a_{10}	Temperature	°C
a_{11}	Weather forecast	SafetyNet / NAVTEX service
a_{12}	Sea and water currents	m/s
a_{13}	Safety of navigation	Marine charts and navigational publications
a_n	Other	Other

Table 2 - Factors of the vessel in meteorological navigation

MARK: B		
Factors of the Vessel in Meteorological Navigation		
Influential Factor Mark	Meaning	Measuring Unit or Source
b_1	Properties of the vessel	Data from the register
b_2	Autonomy of the vessel's navigation	D, h, min.
b_3	Safety of the vessel	Register
b_4	Requirements of the ship operator, freighter and insurer	Contract
b_5	Specific cargo	Bill of lading
b_6	Position of special areas and particularly sensitive areas	Marine charts and navigational publications
b_n	Others	Others

selection of the route from safety and meteorological aspects.

Specific characteristics of cargo refer to its properties. Some kinds of cargo require quick delivery to the destination, hence the shortest navigational routes have to be used (channels, passages, etc.). Such cargoes are usually highly perishable goods, such as cooled cargo and the like. For dangerous cargo (inflammables, radioactive, hazardous for pollution) legal regulations for particular routes and areas are to be observed. In that way the special care areas are to be protected: closed seas, environmentally protected areas etc. [8].

For the purpose of further development of the model it is proposed to group the factors and evaluate them according to *Tables 1 and 2*.

It is evident that a relatively high number of factors important in planning meteorological navigation and determining OMR are measured in different measures or are differently described.

In further development of the model of grouping and evaluating of assessment measures of meteorological factors in planning meteorological navigation the following has to be determined:

1) measures in optimal decision-making, and
2) correspondence to the *ECDIS* system.

4. METEOROLOGICAL ROUTE AND ECDIS

Apart from other reasons for the use of the ECDIS system in navigation, it is also used in maritime meteorology, as it is its integral sub-system. For instance, the use of *ECDIS* allows access to oceanologic, bathymetric, meteorological and other data (*Weather Reports*) [2].

The possibility of planning the meteorological navigational route has not been observed.

In order to make optimal decisions in planning OMR, it is proposed that each influential factor ($a_1 - a_n$, $b_1 - b_n$) has two values:

1) favourable value, and
2) unfavourable value for determining *OMR*.

The favourable value is the value of the factor which allows safe passage of the vessel when navigating in OMR. It is proposed to be marked by one (1).

The unfavourable value would be the value of the factor which does not allow for a safe passage of the vessel when navigating in OMR. It is proposed to be marked by *zero* (0).

Therefore, if at the same time:

$$\sum_{i=1}^{n} a_1, a_2, \ldots a_n = n \qquad (1)$$

and

$$\sum_{i=1}^{n} b_1, b_2, \ldots b_n = n \qquad (2)$$

the route in navigation will be considered as safe.

Such approach allows for programmed decision-making about the change of the route or the change of the navigation in the route.

When designing the programme solution of meteorological navigation it is proposed to use the initial decision-making algorithm in selecting *OMR* in the *ECDIS* system (*Figure 1*).

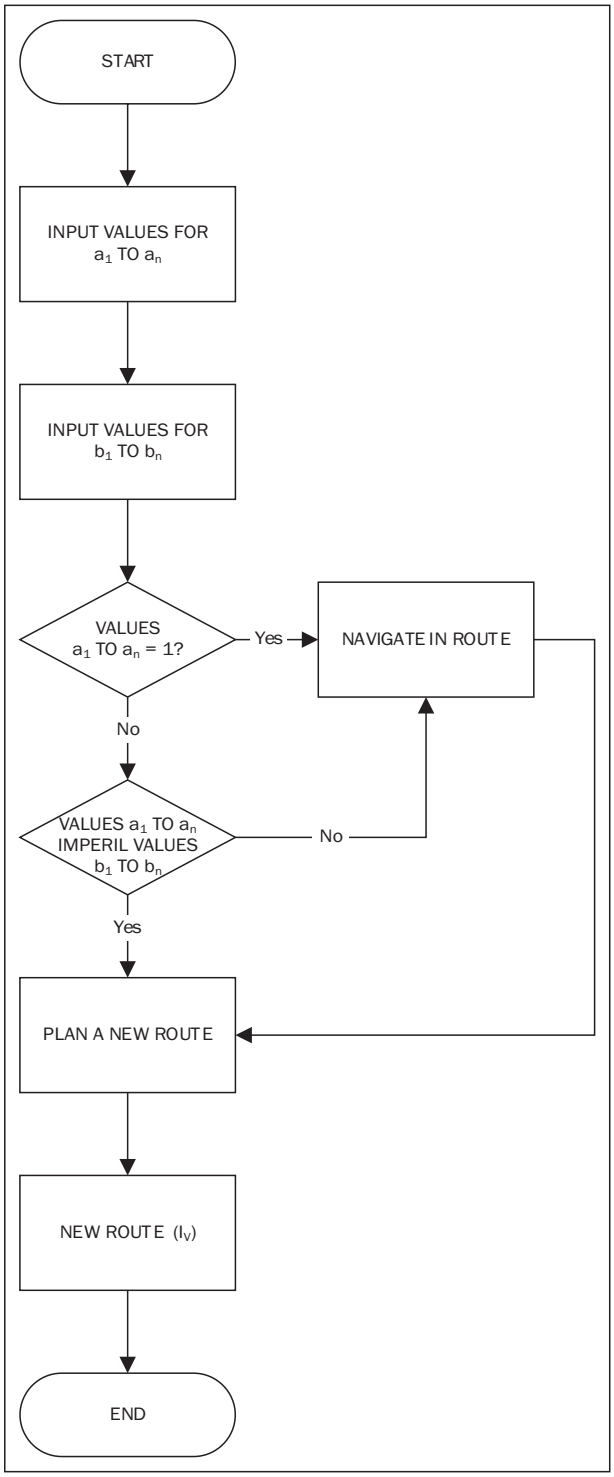

Figure 1 - Initial decision-making algorithm in selecting OMR

In order to complete the programmed solution it is necessary to develop other necessary decision-making algorithms at a lower level of generalisation.

It may be concluded that in determining OMR various managing decisions are made at certain time intervals. It may therefore be assumed that determining OMR is a multi-stage managing process, and the final number of stages may be given:

1) analysis of group A data – stage (p_1),
2) analysis of group B data – stage (p_2), and
3) proposal of *OMR* – stage (p_3).

The following functional model presents the stage of the analysis of group A data (p_1) which are affected by the states (0 or 1) of the values $a_1, a_2, \ldots a_n$ (*Table 1*):

$$p_1 = f(a_1, a_2, \ldots a_n) \quad (3)$$

The following functional model presents the stage of the analysis of group B data (p_2) which are affected by the states (0 or 1) of the values $b_1, b_2, \ldots b_n$ (*Table 2*):

$$p_2 = f(b_1, b_2, \ldots b_n) \quad (4)$$

The following functional model presents the stage of the proposal of OMR (p_3) which is affected by the output values of the decision-making algorithm (l_V) (*Figure 1*):

$$p_3 = f(l_V) \quad (5)$$

Therefore, the determination of OMR may be presented as the function (R) which changes and depends on the stages as shown in the model:

$$R = f(p_1, p_2, p_3) \quad (6)$$

5. CONCLUSION

Meteorological navigation is the selection of navigational route in view of meteorological factors and control of the vessel in heavy weather and safe navigation aimed at the protection of human lives, ship and cargo in heavy weather.

Optimal meteorological route may be the route determined by applying human potential skills and competences and all available technologies in decision-making and implementation of management processes, which achieve the highest accuracy.

In order to increase the available technologies further researches and development are proposed, for instance, development of decision-making algorithms at the lower level of generalisation as the complete programme solution.

It is expected that the implementation of the developed model of planning OMR using ECDIS will substantially contribute to the increase of the level of safety of navigation in areas where it is necessary.

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SAŽETAK

Rutom u pomorskom prijevozu drži se jedan ili više poznatih kursova s kojim se plovi ili se namjerava ploviti. Meteorološki čimbenici dobivaju na važnosti ako ruta prelazi duljinu od 1500 M. [1] Meteorološkom plovidbom drži se odabir plovidbene rute s obzirom na meteorološke čimbenike i vođenje broda u nevremenu, te sigurna plovidba podređena očuvanju ljudskih života, broda i tereta u nevremenu. U radu se predlaže model grupiranja i vrednovanja mjera procjene meteoroloških čimbenika u planiranju meteorološke plovidbe. Preporuča se nadogradnja programa jedinstvenog kartičnog i informacijskog sustava (Electronic Chart Display and Information System - ECDIS) prema prijedlogu u cilju omogućavanja računalnog planiranja meteorološke plovidbe.

KLJUČNE RIJEČI

planiranje putovanja, meteorologija, optimalna ruta, ECDIS

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