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Advantages of decision support system use in port entrance operations on the Świnoujście–Police–Szczecin ports complex example

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Abstract

The risk analysis of ships' accidents leads to the conclusion that one of the most important and dangerous stages existing during a ship's trip is harbour entering and leaving. The use of the modern methods of risk estimation should improve both ship/harbour safety and the economic profitability of the taken decisions. This concerns especially the harbour entering by maximum acceptable size ships for the given harbour. The analysis of the indispensable data sets and the decision model algorithm proposed for the system of Szczecin–Świnoujście ports were described in the article. The use of the decision model, taking into consideration the dynamic current data and hydro-meteorological conditions, including their changes tendency and the possible changes of ship movement parameters, should increase the decision efficiency and hold the same safety level.

Introduction

One of the most risky parts of the ship's trip are port leaving or entering operations. The risk of an accident increases during these operations and can achieve the level at which it should be considered whether such operation in given conditions is safe and the undertaken risk is not excessive. Many types of accidents during port entering operations could be considered (connected to human errors or technical failures) but the risk of grounding or bottom touching is one of the basic existing threats. This concerns especially vessels whose size is near to maximum admissible in the given harbour.

That is why the key factor taken into consideration before port entering operations is the under keel clearance (UKC). UKC is the required minimum distance between the ship's keel and the sea / channel bottom. The determination of the minimum value of UKC for actual weather and port condition and vessel type is very important. This factor can be estimated using many methods.

The Constant Clearances Method (CCM) is the generally applied method in Poland now. This method is based on analytical and empirical assumptions and the minimal UKC value is expressed as the sum of several component of clearances. It allows to determine the safe UKC value before ships enter ports. However, a large established margin of estimation error characterizes this method.

It can lead to a too protective decision and generate additional costs caused by ships stopping at anchor or in harbours. Permission for harbour entering for a large ship is taken on the basis of the analysis of ship maximum dimensions and draught and in reference to actual port regulations. However, such system does not assure the proper regard of current hydro-meteorological conditions. This refers especially to inland ports which can be reached by ships after a long voyage from the entrance of river or waterway (e.g. Szczecin, Police).

Making more elastic decisions, without the possibility of ship's grounding accident, is possible after taking into account actual navigational conditions. The developed in Maritime University of Szczecin probabilistic model of UKC determination makes such calculations possible so it is a good alternative for the Constant Clearances Method [1]. This model was verified successfully in Szczecin–Świnoujście waterway area and is useful in risk assessment of ship entrance to ports. The model of decision support system presented in this paper is a proposition of UKC model extension. The model can be useful in practical decision making problems when harbour workers try to make decisions about large ships entering the harbour. They should also take into consideration potential profits / losses caused by undertaken decisions and the high level of safety for undertaken operations [2].

Use of Event Tree Method in the decision making process

It is possible, among the quantitative methods of risk analysis, to distinguish statistical and probabilistic methods. Probabilistic methods consist in examination of the possibility of appearing individual unfavorable / unwanted events and determining the probability of their occurrence. Estimation of the probability of the emergency situation appearance (unfavorable event) is possible on the basis of the properly constructed event tree. Event Tree (ET) is a graphical model of an accident scenario that yields multiple outcomes and outcome probabilities that can result from a specific equipment failure or human error [3].

Event Tree Method (ETM), used to the qualitative accidents analysis, enables a detailed investigation of the primary unwanted event appearance reasons and the event scenarios course (e.g. the accident, catastrophe) after their appearance. It is used when unwanted primary events appeared and there are some difficulties with danger estimating. In this context, the risk can be defined as the relative possibility of the rise of loss in the result of single unwanted event appearing.

ETM enables a detailed investigation of the reasons for the primary unwanted event appearance and the scenario course of the events analysis after their appearance (e.g. accident, catastrophe). It is applied when difficulties connected with threat estimation appear and they are related to primary unwanted events arising (Fig. 1).

The borne costs analysis should consider the possible similarities and mutual relations between defined appearing events. It could lead, for the given case, to the whole scheme and procedure of the risk management simplification. The event tree use in the risk assessment process should be executed according to the determined scheme of the proceeding.

Therefore, it should:

a) define the problem for analysis;
b) identify unfavorable, possible events (risk factors);
c) identify measurement methods of determined risk factors;
d) estimate the relative probabilities of events in every possible scenario (event runs) for each risk factor;
e) count the consequences of every scenario, by the augmentation of probabilities (or the frequency) of consecutive events in a given scenario by their results;
f) count the economic value of the risk for every scenario.

The costs analysis should lead to establish such risk level which can be accepted because of avoidance costs (they will be larger than costs borne when the accident appears). The ship draught is the most important factor influencing assessed risk costs in the aspect of the probability of an accident, appearing during port entering.

Specifics of the ship operation in restricted areas

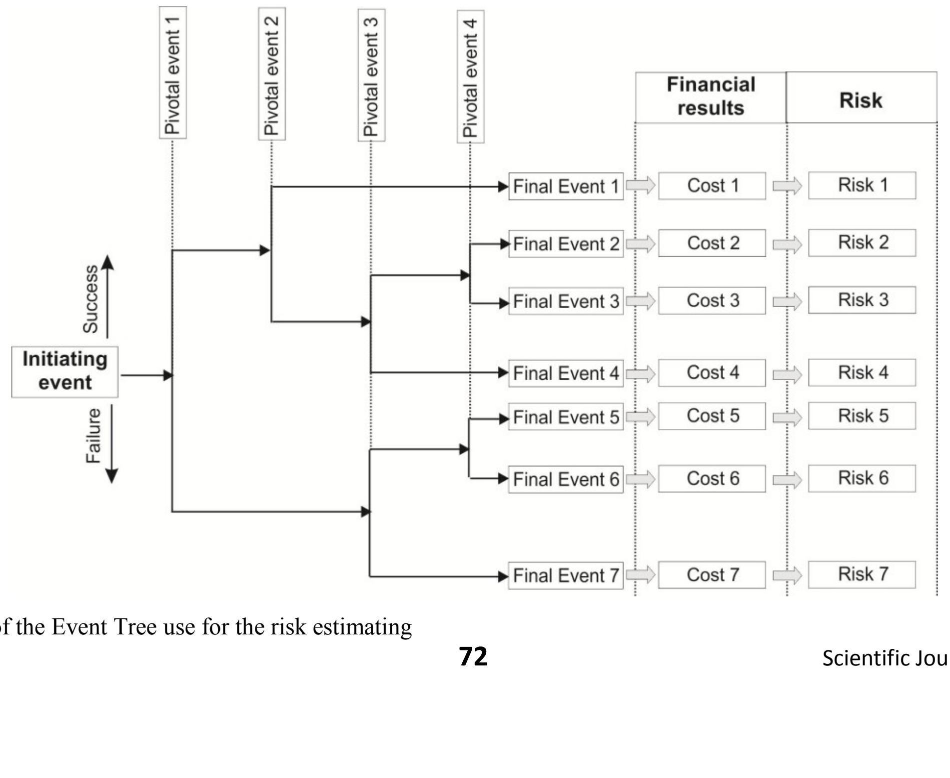

Fig. 1. Example of the Event Tree use for the risk estimating

(ports, rivers, waterways) obliges the decision-maker to regard many factors closely connected both with the ship/ environment safety and maritime companies economic results. Establishing too rigorous regulations can result in measurable financial losses.

The possibility of the successful port entry operation in given conditions will raise concerns first for the ships which are on the boundary of the port standards fulfillment or can fulfill them only when keeping suitable parameters value during the entering operation (e.g. navigating at reduced ship speed in relation to that described in port regulations for squat effect decreasing).

The system supporting the decision making process should take into consideration ports specifics so it cannot have the universal character (except general system principles). But in every case it should consider navigational, environmental, weather and other important conditions usually present in the port area and approaches. It seems that it is easiest to define such conditions for ports established as separate administrative units additionally with the direct access to the sea.

On the opposite pole are complexes of many ports lying along inland water and river, which are strongly dependent on transfer possibilities of this water road (it is possible to block the whole entrance to the port/ports by other ship accidents which can happen not only in the port area but also on the river or other place of waterway).

The accident costs or the unnecessary ship delay are the last necessary factor needed to estimation. The following cost groups, which should be considered in the accident risk value calculation, can be distinguished:

a) ship's costs:
   - costs of the assist of other ships / towing costs;
   - costs of emergency loading / discharging operations;
   - costs of the possible repair of the ship;
b) environment / area costs:
   - costs of the antipollution protection;
   - costs of removing the contamination waste caused by accidents;
   - costs of infrastructure repairs;
c) port costs:
   - costs of ports work break / the maritime sector companies losses;
   - delay costs of ships blocked in ports.

On the other hand, it is necessary to calculate demurrage costs arising during waiting for the improvement of sailing conditions or possible costs of ship discharging at anchor for its draft reduction.

The decision model of the ship entry to port on the example of the complex Świnoujście –Police–Szczecin ports

As mentioned before, to determine the necessary under keel distance value the constant clearances method is most often applied. It consists in the qualification of following partial clearances:

R1 – the inaccuracy of the hydrographic depth measurement clearance;
R2 – navigational clearance;
R3 – the low water level clearance;
R4 – the sea bottom mudding clearance;
R5 – the weaving clearance;
R6 – the increasing of the draught of the vessel in fresh water clearance;
R7 – the vessel trim and list clearance;
R8 – the aft squat clearance;
R9 – the vessel squat clearance.

Clearances R1–R5 are connected to the navigational area type and they mostly have steady character for the given sailing area. This is the main reason of unnecessary increasing of the required minimum value of UKC. The good example is R3 clearance for the low water level whose values were calculated as follows: 0.6 m for Gdańsk and Gdynia, 0.75 m for Kołobrzeg and 0.5 m for Szczecin and Police, and it reached even 0.8 m value for Świnoujście. Such water states should be obviously taken into account, but when mean water tide is stable and increases the average state, this correction should be skipped. Of course in case of a longer trip along a restricted area or river, the dynamic decreasing of water level should be also considered. However, such change should be determined on the basis of statistical studies and chosen for the least favourable scenario. The possible decreasing of water level during the trip along Świnoujście–Szczecin waterway was determined and it should not violate 0.1 m.

In order to increase the prognosis accuracy, the number of measuring instruments, enabling the remote survey of the water level and the automatic data updating, should be increased. Obtained data could be properly used for better tide prognosis and better grounding risk calculation without unnecessary reserves. Frequent measurements of the water tide will allow to define the current tide tendency in ports and along waterways (the water level descent or the growth on the navigational area). The current measuring points distribution is not sufficient because they don't assure optimal decision. The number of measuring instruments should be enlarged, and their positions should evenly cover the whole length of the waterway from Świnoujście to Szczecin. The proposed positions of the remote water level measurement are following (Fig. 2):

a) The breakwater Świnoujście – 1 km;
b) The Fuel Base of Świnoujście – 5 km;
c) Zalew Szczeciński BT1 – 16.5 km;
d) Trzebież – 36 km;
e) Police – 48 km;
f) Szczecin Obrotnica Przesmyk Orli – 64 km.

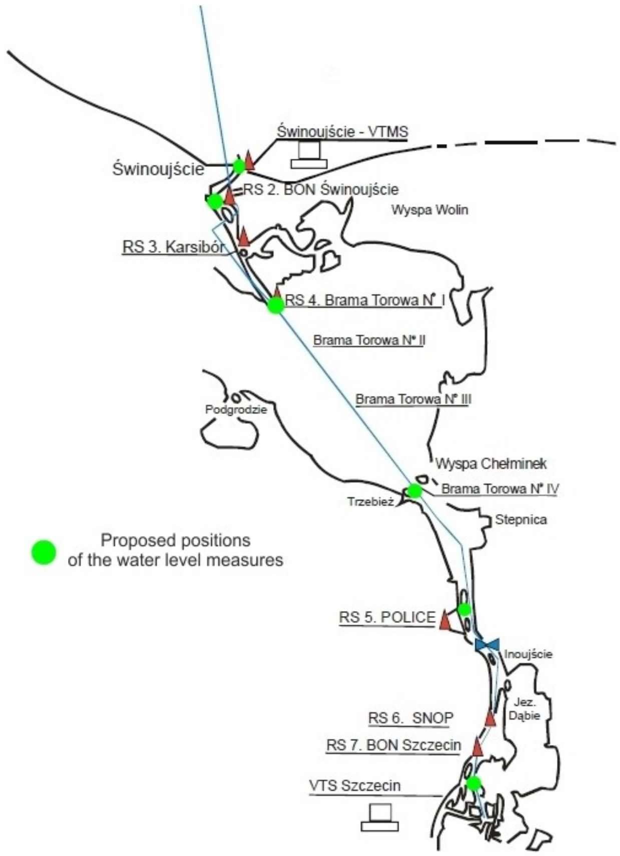

Fig. 2. The water level remote measuring stations allocation – Szczecin–Świnoujście waterway

Clearances R6–R9 are connected to the ship movement and the ship interaction with water and port structures. Clearance R6 can be skipped in the whole cycle of calculations if the draught of the ship for fresh water will be the input data. Remaining component are connected with the draught increasing when ships are moving through restricted areas and it is the natural phenomenon on shallow water areas.

The probabilistic model of UKC calculation is a good alternative for the method of constant clearances method. The basic principles of this model were introduced in [2]. The most important factors considered during the building of the probabilistic model of under keel clearance determination are:

a) input data statistical variation (e.g. ship draught, the water);
b) measurements uncertainty (the ship draught, sounding values, the measurement of the water level);
c) used models (the movement of the ship, rolling, ship draught changing);
d) the prognoses of factors having the influence on decision (the change of the water level, waving).

Following computational blocks consist on the model:

a) the random ship draught calculation block (with regard to the mistake of the draught and the list assessment);
b) the water level calculation block;
c) the depth calculation block (with regard to the level of water in the harbour);
d) the ship's squad calculation block (working on the basis of 6 most popular ship's squad estimating methods);
e) the UKC calculation block.

It is obvious that the essential factor that should be taken into consideration (especially in case of heavy drafted ships in relation to the accessible depth of the navigable area) is the permissible ship speed in the defined waterway sections.

According to [4] ship speeds permissible on the waterway Szczecin-Świnoujście are presented in table 1 and figure 3.

Table 1. Maximum permissible ship speeds in separate sections of the Szczecin–Świnoujście waterway [4]

No.	Waterway section	Max. speed [kn]
1	From sea anchorage to buoys No. 7–8	12
2	From pair of buoys No. 7–8 to waterway Gate No. 1	8
3	From waterway Gate No. 1 to abeam of northern head of Chełminek Island	12
4	From abeam of northern head of Chełminek Island to buoys No. 13–14	8
5	From buoys No. 13–14 to abeam of beacon Krępa Dolna	12
6	From abeam of beacon Krępa Dolna to abeam of beacon Raduń Górna	8
7	From abeam of beacon Raduń Górna to Iński Nurt	12
8	From Iński Nurt to port of Szczecin and in port areas	8

Yet, the recorded speeds analysis carried out in [5] leads to the conclusion that ships on the waterway Szczecin–Świnoujście navigate at reduced speed and don't achieve admissible maximum speed values. For this analysis waterway was divided to 5 sections as follows:

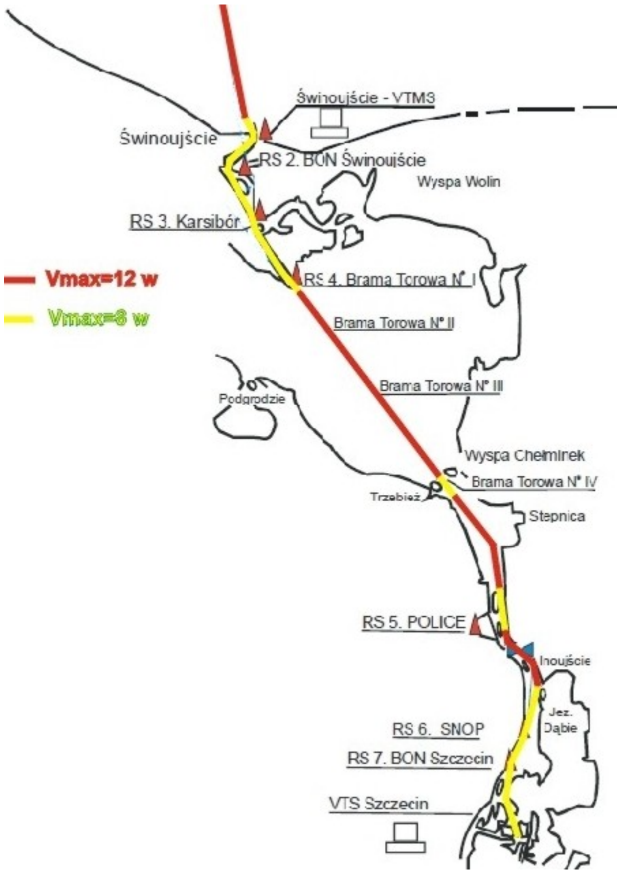

Fig. 3. Maximum admissible speeds on the Szczecin–Świnoujście waterway

I: Świnoujście breakwater to Karsibór ferry crossing;
II: Karsibór ferry crossing to Waterway Gate No. 1;
III: Zalew Szczeciński area;
IV: Waterway Gate No. 4 to Police;
V: Police to No. 5 Dock.

The analysis of the average ships' speeds according to the ships' size, recorded on the waterway Szczecin-Świnoujście, leads to the conclusion that large ships (ship length $L > 150$ m) move at lower speeds than small ships (Fig. 4). Insignificant crossing of the allowed speed for smaller ships (the length less than 150 m) in section 5 appeared because the admissible speed of 12 knots is allowed at some parts of this section. However, large ships manoeuvre with a lot of smaller speeds than admissible.

Clearance connected with ship squad can be dynamically modeled factor, so in the proposed support system it is possible to recommend the ship speed reduction in some parts of waterway to enable port entering without ships delay. In case of the first negative decision (too high level of accident risk) the system will iteratively calculate the possibility of ship speed decreasing for safety improvement to the level which can accepted.

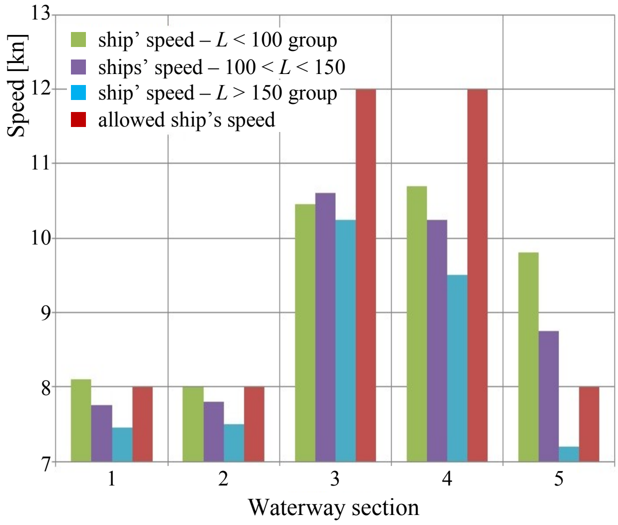

Fig. 4. Average ship speed values on the Szczecin–Świnoujście waterway according to ship length [5]

The decision support system algorithm was presented in figure 5. The waterway was divided into logical sections regarding the destination harbour, the area type and the financial results of the waterway blockade.

Such approach allows to divide the conducted analysis into separate parts and easily calculate average costs depending on the possible accident position. Waterway blocking in various positions will have different financial consequences for Świnoujście, Police or Szczecin harbours. It should be taken into consideration that rescue action costs and possible environment contaminations removing costs will be different for an accident in Pomerania Bay or in Piastowski Canal.

The easy implementation of the algorithm is possible to very different area types because of the possibility of separate analysis of the consecutive sections of the navigational area. It is very important for inland ports.

Conclusions

In decision making process it is very important to take into consideration both, safety and financial factors. Because of this, the block of the cost calculation of an incident is a very important unit of the proposed system.

Most complicated environmental conditions cause difficulties in proper situation assessment. Use of traditional methods could cause additional costs. Support decision systems properly adopted to local conditions should improve decision efficiency and financial results without safety level decreasing.

The properly working system, having actual data, will allow to monitor and make the decision in the real time without unnecessary delays.

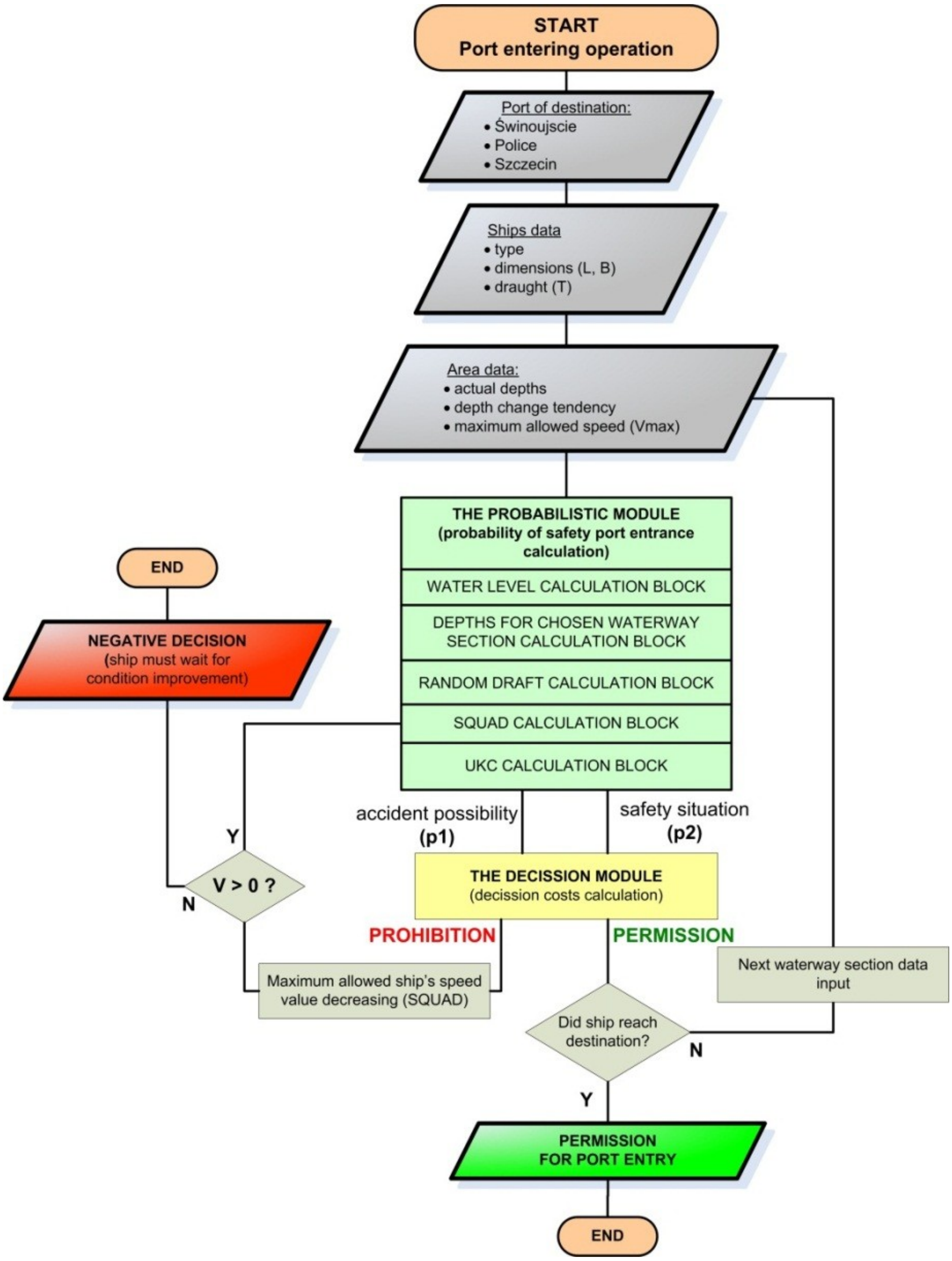

Fig. 5. The algorithm of decision supporting system for Szczecin–Police–Świnoujście complex of ports example

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