



Benchmark of Turning Basin Options for the ECMT Class V Network of Nord-Pas-de-Calais (France)

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Abstract. The Nord-Pas-de-Calais Division of Voies navigables de France (VNF), the French Waterways authority, is preparing a master plan for the development of turning basins for its ECMT class V network. In this frame, IMDC has been asked to carry out a comparative analysis (benchmark) of the different designs of turning basins in France and elsewhere in the world and to propose design criteria adapted for future developments (for ships of 110 m and 135 m) on the Nord-Pas-de-Calais network. The first part of the study consisted in a desktop review of available national and international guidelines or recommendations on the subject of turning basins design. This helped building a better understanding of the needs in terms of geometry for safe and/or comfortable turning maneuvers. Technical studies of built or projected turning basins on the Nord-Pas-de-Calais network were also analyzed to refine the knowledge on local conditions. Based on the findings of the desktop analysis, interviews of European waterways authorities, international experts and skippers were carried out to further improve the understanding of the problem, both from the infrastructure side as well as from the users' side. On top of geometry concerns, the interviews tackled hydrometeorological constraints, operational and environmental aspects, auxiliary equipment, etc. From this, a draft technical reference system was proposed for future turning basins on the Nord-Pas-de-Calais network. It proposes two options, depending on whether the basin is located on two banks or on one bank only, and aims at offering each option in two safety and ease levels: a comfort level version, on which the turn must always be relatively easy, and a safety level version, on which the turn must always be possible, but with less ease. The designs were then tested using real time navigation simulations. Optimizations of some of the designs were also proposed to adapt to severe hydro-meteorological conditions. Finally, a decision tree has been developed to facilitate the selection of a design solution according to the local characteristics of the projected basin location on the network. This tool allows the selection of the geometry allowing the easiest turn possible according to the available space and the hydrometeorological conditions present on the envisaged site.

Keywords: Waterway infrastructure · Turning basins · Navigation · Hydraulics · Ship simulator

1 Introduction

The Nord-Pas-de-Calais ECMT Class V network will play a major role in linking the Canal Seine-Nord Europe to the ports of Dunkirk and the inland navigation network of Flanders and Wallonia (Belgium), and connected ports in the Scheldt-Rhine delta such as Ghent, Antwerp or Rotterdam.

The future commissioning of the Seine Nord-Europe Canal and the prospect of 24-h navigation should result in a significant increase in traffic, particularly of vessels of 110 m and 135 m.

The Nord-Pas-de-Calais Division of Voies navigables de France (VNF), the French waterways manager, is therefore preparing a master plan for the development of turning basins for ships of up to 135 m on the ECMT class V network. Within this masterplan, VNF has hired IMDC and its subcontractors Flanders Hydraulics (FH) and Ghent University to propose well suited geometries that can be applied in all locations and conditions on the network (Fig. 1).

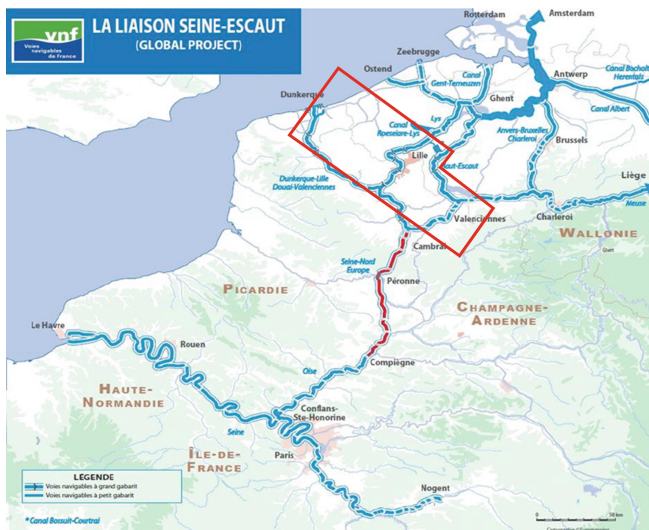


Fig. 1. The ECMT class V Nord-Pas-de-Calais network (circled in red) in the Seine-Scheldt environment (source: VNF)

The network has a total length of 240 km and, on most of its length, has a width of 34 m at 3.5 m depth. It is situated in a rather highly urbanized environment. From a hydrometeorological point of view, the canalized rivers of the network (Deûle, Lys and

Scheldt Rivers) can be host to significant currents while strong wind conditions (5 Bf and above) are more frequent at the coast (Dunkerque area) than more inland.

The proposed turning basin geometries shall be suited to all envisaged locations, with varying hydrometeorological conditions (current and wind), availability of (both or only one) banks for construction, environmental or land use constraints while guaranteeing satisfactory operational conditions and for limited costs. For each of the proposed designs, the study aims to define a minimum safety geometry allowing safe turning considered and a geometry with larger dimensions, allowing turning under better comfort conditions, always whatever the location and conditions considered on the ECMT class V network of Nord-Pas-de-Calais.

In a first phase, a desktop review of available national and international guidelines on the subject of turning basins design as well as of technical studies of built or projected turning basins on the Nord-Pas-de-Calais network is performed. Based on the findings of the desktop analysis, interviews of European waterways managers, international experts and skippers are carried out to refine the understanding of the constraints at stake. From this, propositions of well-suited geometries of turning basins are made. Finally, these geometries are tested on real-time navigation simulators and, in some cases, optimized.

2 Design Ships

The study focuses on ECMT Va class vessels of 110 m and 135 m (the latter is named “Va+” below). The vessels studied are container ships since this type of vessel is the most constraining when turning in windy conditions. The draft in loaded condition is taken equal to that of a loaded bulk carrier (2.5 m) in order to guarantee the validity of the simulations for loaded bulk carriers as well (since container ships generally have smaller drafts) (Table 1 and Fig. 2).

Table 1. Main dimensions of the design ships

Class	Length [m]	Beam [m]	Draft loaded/empty [m]	Air draft loaded/empty [m]
Va	110	11.4	2.5/1.7	3.4/4.2
Va+	135	11.4	2.5/1.7	3.4/4.2



Fig. 2. A 110 m-long ship on the ECMT class V Nord-Pas-de-Calais network

It should be noted here that on canals or canalized rivers with relatively weak current (which is the case of the study area), a ship can always turn empty except in exceptional cases. Exceptions are either rare (diversion of deliveries, unexpected and prolonged closures of the channel or of a lock) or limited to bulk carriers and avoidable (bulk loading generating dust settling in the deckhouse).

In terms of steering aids, both design ships are equipped with bow thrusters. On European waterways, this type of equipment is mandatory on any vessel longer than 110 m (Va+ class in this case) and it is present on the majority of current Va units.

3 Literature Review

The first step of the literature review consisted in studying recommendations related to turning basin design in national and international guidelines and recommendations.

The sections related to turning basins in the Dutch (RWS 2017), German (BMVBS 2011), French (Ministère de l'Équipement 1995), Chinese (PIANC 2019), Russian (PIANC 2019) and American (USACE 2006) guidelines were studied as well as in the PIANC InCom WG 141 recommendations for the design of inland waterways (PIANC 2019). It is worth noting that the main features of national guidelines in relation to turning basins design are recapitulated (and translated) in the annexes to the WG 141 report.

The guidelines which are more applicable to the studied case are the Dutch and the German guidelines as they both target the design ships of the study. The French directive, which is of application in the present case, does not make recommendations pertaining to turning basins. Other consulted guidelines are less applicable in the present case as, for instance, some consider sea going ships only (US guidelines) or ships with much lower maneuverability or sailing on rivers with much stronger current (Chinese guidelines).

For waterways of medium traffic density, which is the case of the studied network, the Dutch guidelines recommends circular geometries with a diameter of $1.2 L$ (L = length of the ship). It must be noted that this is applicable to canals or rivers with a current lower than 0.5 m/s which is the case in more than 95% of the time in the study area.

On the other hand, the German guidelines recommend using basins of trapezoidal shapes. The case of 110 m and 135 m inland ships is specifically addressed in the guidelines. For both ships, a distance from the waterway axis to the small base of the trapeze equal to the length of the ship ($1 L$) is proposed (see Fig. 3). No indication is given for the dimension of the larger base or for the angles of the trapeze.

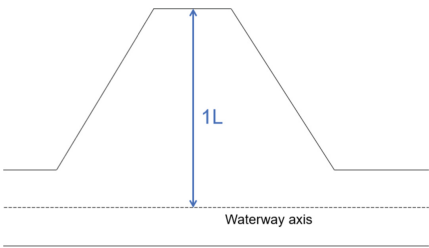


Fig. 3. Turning basins dimension for 110 m and 135 m ships in the German guidelines (L: length of ship)

The PIANC recommendations build on the above-mentioned guidelines and propose a dimension of 1.2 L (for a quality of driving C¹) with no indication on the shape of the basin (circular or trapezoidal) (see Table 2). The size of the basins should be chosen according to the targeted level of accessibility (quality of driving). The report however acknowledges the presence of turning basins of 1.15 L (and less) in Europe.

Table 2. Minimum width of turning basins (including safety allowances) as a factor of ship dimension from existing guidelines (PIANC 2019). Minimum widths for sheltered water and canals are circled in red.

	Open water	Sheltered water and canals	Quality of driving
	Free-flowing river	Canals	
China	2.5 L (4.0 L)*	2.0 L	A-B
Dutch	case by case	1.2 L	C
Germany	case by case	1.2 L	C
US	1.5 L**	1.2-1.5 L**	A-B
Recommendation of WG 141	1.5 L free turn and 1.2 L fixed turn	1.2 L free and fixed turn	C

(*flow velocity >1.5 m/s), (** US figure is for sea-going ships, no figure is given for IWT, flow velocity < 0.8 m/s)
Remarks concerning WG 141 recommendations: 1.5 L was chosen according to the US guidelines, 1.2 L according to geometric aspects. Because turning is generally a challenging manoeuvre, the S&E quality will always be C

The PIANC recommendations (PIANC 2019) also indicate that hydrometeorological conditions (wind and current) must be taken into account. A formula is suggested for lengthening the basins of rivers with significant current. This formula is based on the hypothesis of a drift not compensated by the pilot, which is generally not the case during a turning maneuver in a confined environment such as a canal or river.

¹ Quality of driving C corresponds to a strongly constricted drive, as opposed to quality of driving A (nearly unrestricted drive) or B (moderate to strongly restricted drive) (PIANC, 2019).

The formula is therefore not applicable in the context of the study as it would lead to excessive basins lengths.

In a second phase, existing or studied turning basins on the ECMT class V network of Nord-Pas-de-Calais were studied. This helped better understand the constraints to be taken into account for the design of turning basins in the study area (wind, current and lack of available space, mainly). In the reviewed studies, the proposed geometries were either circular or trapezoidal with dimensions ranging from 1.1 L to 1.3 L.

It is worth noting that, although most studies acknowledge the interest of keeping the turning basins outside of the navigation channel as much as possible, all proposed designs integrate the entire channel (in order to limit the excavation costs, and to avoid additional expropriation costs). This is also true for most of the existing turning basins on the Nord-Pas-de-Calais network.

Amongst the reviewed turning basins studies, the report of a turning basin project in Arques (FH & Ghent University 2017) for ships of 135 m and 143 m on either circular or trapezoidal geometries supported by navigation simulations helped better evaluate safety and ease level of the turns on such geometries and under the hydrometeorological conditions of Nord-Pas-de-Calais.

Finally, a short analysis of the existing turning basins (geometries, dimensions, etc.) was also carried out, to serve as input when considering upgrades (enlargement) of existing turning basins.

4 Interviews of Skippers, Waterway Managers and Experts

With the knowledge acquired in the previous phase, a questionnaire was drafted to refine the understanding of the problem by means of interviews of waterways authorities, international experts, and skippers. In total, seven employees of waterways authorities (VNF in France, DVW and SPW in Belgium and RWS in the Netherlands), six international experts and six skippers, from various countries have been interviewed. This enabled a better understanding of the problem from both the side of the user as well as the side of the infrastructure provider. Information related to bank protection for turning basins, equipment (signaling, lighting, mooring, etc.), waterway maintenance and management (dredging, impact from and on traffic, etc.) was also collected.

Most experts or waterway managers referred to Dutch, German or PIANC guidelines and to circular or trapezoidal geometries with dimensions of 1.2 L to 1.3 L being the most commonly cited options. Many also pointed to the fact that ship maneuvering simulations are recommended by most guidelines in case of strong current or wind. There was a wide consensus on having a depth equal to the depths of the waterway, with many pointing to the fact that large under keel clearances (UKC) have a positive impact on the ease of the turn.

Skippers tend to prefer circular geometries for ease of maneuvering but confirm that trapezoidal geometries are also interesting options. Moreover, they are often obliged to turn in much narrower basins and mention that basins of 1.1 L width or less are not uncommon.

5 Proposition of Geometries Suited for the ECMT Class V Network of Nord-Pas-de-Calais

From the information collected above, two main designs have been proposed: a circular shape for situations where both banks of the canal or canalized river can be used and a trapezoidal shape when the turning basin can only be built on one bank of the waterway. For both options, two sizes are proposed based on information collected in the previous phases of the study: a larger one which is expected to allow comfortable turns in all conditions and a smaller one, which is designed to be sufficient to allow turns, though with less ease.

5.1 Option N°1: Circular Geometry, Using Both Banks of the Waterway

A circular geometry has the advantages of allowing simpler (circular) maneuvers while keeping excavation volumes limited. It also is the most commonly encountered geometry on the Nord-Pas-de-Calais network and its users are therefore very well accustomed to it. The main disadvantage of this solution is the total interruption of traffic when a turn is performed, regardless of the size of the turning ship. If such interruption is deemed unacceptable, a single bank solution (trapezoidal) should be considered.

Both small and large sizes of the proposed circular geometry are shown in Fig. 4.

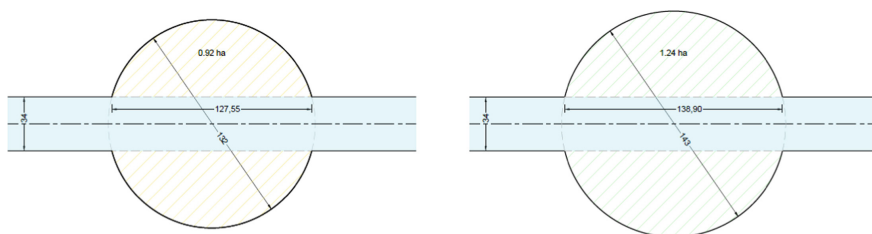


Fig. 4. Proposed circular geometry for 110 m ships using both banks of the waterway, small size (left) and large size (right). The channel is shown in blue and the area to be excavated in hatching

5.2 Option N°2: Trapezoidal Geometry, Using Only One Bank of the Waterway

The advantages of this option are mainly land use (and budget) related. Indeed, it is the solution that requires the least amount of space when the basin must be located on a single bank and therefore potentially minimizes excavations and land acquisitions. Also, by being positioned off-center, this geometry does not imply a systematic interruption of the traffic during turns, at least not during the turns of ships of smaller dimensions than those of the design ship.

On the downside, the two-stage maneuver, which must be carried out on this type of basin, is more complex and more time-consuming than the one-stage circular maneuver, but it is nevertheless commonly practiced by all skippers. Finally, this trapezoidal solution is not yet widely used on the Nord-Pas-de-Calais network and the services in charge of waterway maintenance might have to get accustomed to this new design. The skippers should not encounter major difficulties in using such basin, since they are already used to turning in various types of geometries (wide portions of the waterway, junctions, etc.).

Both small and large sizes of this geometry are shown in Fig. 5.

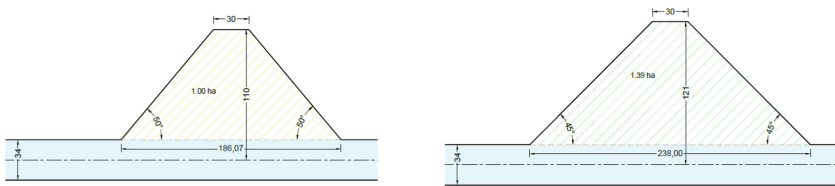


Fig. 5. Proposed trapezoidal geometry for 110 m ships using only one bank of the waterway, small size (left) and large size (right). The channel is shown in blue and the area to be excavated in hatching

The base angles of the trapezoid are chosen based on results of navigation simulations on ships of 135 m on similar geometries in the study of the turning basin in Arques cited above (FH & Ghent University 2017).

6 Check of Accessibility and Optimization of the Proposed Geometries by Means of Real-Time Navigation Simulations

All proposed geometries have then been tested on the real-time navigation simulators of Flanders Hydraulics (FH) in Antwerp, Belgium.

The parameters of the study (ship classes, geometries, hydrometeorological conditions, basin positioning, etc.) are numerous and the number of possible scenarios (several thousands) greatly exceeded the material possibilities of the study. A two-phased approach was therefore used for the real-time simulations: a first phase of exploratory simulations, during which the impacts of the different criteria were analyzed, and a second phase, during which the most relevant scenarios (key scenarios) were studied.

6.1 Results of the Exploratory Phase

6.1.1 Analysis of the Impact of the Simulation Parameters (Current, Wind, Ship Draft, etc.)

6.1.1.1 Impact of the Hydrometeorological Conditions

The selected current velocities and wind speeds for the simulations correspond to strong but not extreme conditions (values not exceeded 95% of the time). Currents up to 0.4 m/s and wind speed up to 5 Bf depending on locations were computed and introduced in the simulators.

In the case of trapezoidal basins, turning in the upstream direction is more difficult than turning in the downstream direction. This is because the stern of the ship is in a current that opposes the rotation of the ship, causing it to drift toward the edge of the basin. On the other hand, turning after approaching in the downstream direction is easier because the current drags the stern of the ship and makes it turn in the desired direction. The result is a smooth and centered maneuver in the basin (Fig. 6).

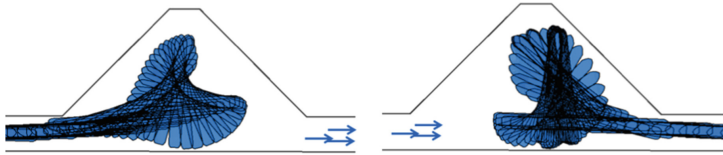


Fig. 6. Large trapezoid for a 110 m ship, sailing downstream (left) and upstream (right), with a current of 0.4 m/s. In the case of the upstream turn (right), the shorter distance to the banks and the lower fluidity are clearly visible.

In the case of circular basins, the direction of the current has no influence because of the symmetry of the layout.

Transverse wind was identified as the most unfavorable regardless of the type of basin (circular or trapezoidal).

The unfavorable effect of the wind is further illustrated in Fig. 7 where the maneuver is performed very close to the side opposite to the wind direction for instance.

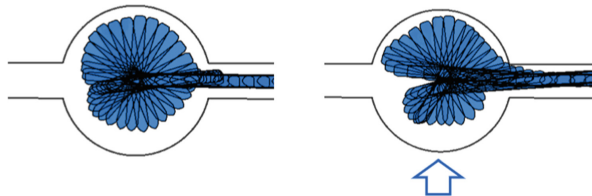


Fig. 7. Influence of the wind in a circular basin. Condition without wind (left) and with crosswind (blue arrow) 5 Bf (right)

6.1.1.2 Impact of Ship Draft

In the case of the circular basins, empty ships (i.e. ships with empty containers) are the more critical ships in windy situations, as shown in Fig. 8. Indeed, empty ships lead to an increased effect of the wind which is not counterbalanced by the better underwater maneuverability.

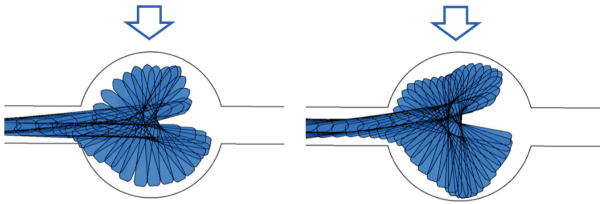


Fig. 8. Impact of the draft on turns on circular basins in unfavorable wind condition (5 Bf transverse), empty ship (left) and loaded ship (right). Note: the contact in the empty ship maneuver (left) is due to reduced visibility on the simulator and could have been avoided.

In the absence of wind, the loaded condition is the most critical, as shown in Fig. 9, since maneuverability is reduced by the high draft.

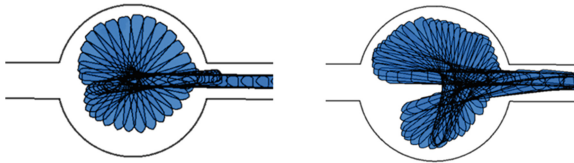


Fig. 9. Influence of loading on turns on circular basins in the absence of wind. Empty ship (left) and loaded ship (right).

In the case of trapezoidal basins, the loaded condition is more critical even in the presence of wind, as shown in Fig. 10. Indeed, in a trapezoidal basin, the ship makes a turn to enter the basin. This maneuver is more difficult in the loaded condition since the reduction in maneuverability of a loaded ship compared to a light ship outweighs the difficulty associated with the increase in windage area of an empty ship (empty containers) during the turn.

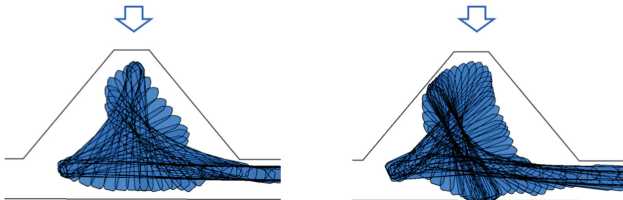


Fig. 10. Influence of draft on trapezoidal basins, empty ship (left) and loaded ship (right) in wind condition (5 Bf transverse)

The impact of other parameters, such as basin positioning (left or right bank, in a straight line or a curve, etc.) were studied but are not described here.

6.1.2 Optimization of Certain Geometries

The tests performed in the exploratory phase revealed a too constrained space in the small trapezoids and optimizations of this geometry were proposed, the objective remaining to guarantee the turns in unfavorable hydrometeorological conditions in a geometry of reduced size.

Two optimized geometries have been proposed depending on whether the solution is limited to a single bank or whether it can occupy both banks (e.g. the case of the enlargement of a circular basin occupying both banks) The optimizations were performed using an overlay of the simulation trajectories and are shown at Fig. 11.

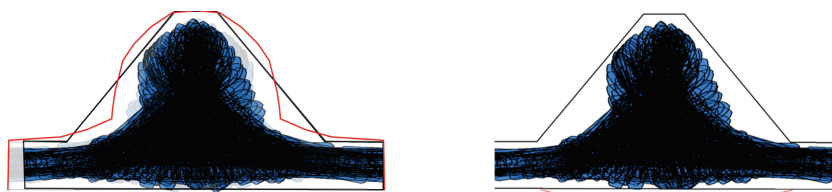


Fig. 11. Principle of the optimization of the small trapezoid (in red), optimized geometry on one bank only (left): rounded top and opening from the channel following the approach paths and optimized geometry using both banks (right): widening of the channel on the opposite bank

6.2 Results of the Second Phase of Simulations

Over both phases of simulations, 97 simulations were performed, and 85 results were deduced directly from simulations results.

Results showed that the proposed large circle allows for an unconstrained turn (of empty ships) while the small circle allows for a constrained turn (of the same ships). These geometries therefore meet the desired high and low quality of driving objectives as defined in the introduction. It is also worth noting here that turns of loaded ships are possible in all hydrometeorological conditions, though with less ease, on these basins.

Results for the trapezoidal geometries (large trapezoid and small optimized trapezoid) showed similar results for empty ships at the exception of the case of a construction on a river (with current) and when the smaller base would be oriented towards the direction of the prevailing winds. In such case, turns proved to be impossible for all trapezoidal basins. Tests on optimized geometries showed the improved ease of driving compared to that of the original small trapezoid. It must be noted here that on the numerous stretches with no current on the Nord-Pas-de-Calais network (canals), the large and small optimized trapezoids can be used regardless of the orientation and meet the desired high and low quality of driving objectives.

To facilitate the decision making of VNF, a decision tree was proposed. It allows to determine the most appropriate geometry (the one that allows the easiest turn) according to the availability banks (both or only one), the available space, the presence

or absence of current and the possibility of arranging the basin so that the top of the trapezoid is not oriented in the direction of the prevailing winds.

7 Conclusion

A study was performed to identify turning basin geometries which allow turns of ships up to 135 m in any location of the Nord-Pas-de-Calais network, with varying hydrometeorological conditions (current and wind), availability of (both or only one) banks for construction, environmental or land ownership constraints while guaranteeing satisfactory operational conditions and for limited costs.

The first phase of the study consisted in the review of national and international guidelines in relation to turning basins design as well as the analysis of past turning basins studies and existing turning basins on the Nord-Pas-de-Calais network. In a second phase, interviews of waterways authorities' staff, international experts, and skippers were performed to better understand how the information collected in the first phase should be applied to the case of the studied network.

From this, geometries were proposed for the future turning basins of the Nord-Pas-de-Calais. Two options were proposed, depending on whether the basin can be located on two banks (circular geometry) or on one bank only (trapezoidal geometry), and are given in a comfort level version, for which the maneuver must always be relatively easy, and a safety level version, for which the turn must always be possible, potentially with less ease.

These draft geometries were then tested on real-time navigation simulators in order to demonstrate their accessibility and to potentially propose improvements. Optimizations of the trapezoidal geometries were proposed to adapt to severe hydrometeorological conditions, for a single or double bank implementation.

The results show that circular geometries allow the turn in all circumstances and can be retained according to the available space between a comfort level (diameter 1.3 L) and a safety level (diameter 1.2 L). Optimized trapezoids allow for easier turns but are not suitable when the small base is oriented in prevailing wind direction when applied on rivers (with current). On the canals sections of the network however, the proposed trapezoidal geometries did give the desired results, in other words: comfortable turns on the large trapezoid and safe turns on the small (optimized) geometries.

Finally, the results have been compiled in a decision tree which will facilitate the selection of a design solution according to the local characteristics of the projected basin location, keeping in mind that a certain flexibility will be required in the application of the proposed designs since local constraints often complicate the application of generic solutions.

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References

- BMVBS (2011) Richtlinien für Regelquerschnitte von Binnenschiffahrtsskanälen
- FH & Ghent University (2017) Etude de trajectographie du bassin de virement d'Arques – Simulations complémentaires
- Ministère de l'Équipement (1995) Circulaire 76.38 modifiée par la circulaire 95.86 relative aux caractéristiques des voies navigables
- PIANC (2019) Design Guidelines for Inland Waterway Dimensions. InCom WG 141
- Rijkswaterstaat (2017) Richtlijnen Vaarwegen RVW 2017
- USACE (2006) EM 1110-2-2602. Hydraulic design of deep-draft navigation projects

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