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UPDATE PIANC INCOM WG 141 DESIGN GUIDELINES FOR INLAND WATERWAYS

by

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ABSTRACT

The PIANC INCOM WG 141 was founded in 2010 to provide planners of inland waterways with design standards for inland vessels in accordance with those for sea-going vessels, worked out e.g. by PIANC MARCOM WG 49. It came out that the MARCOM approach seems generally not applicable for inland waterways, especially because of the better steerability of inland vessels, the lower ship speeds and the lower damages in case of accidents. Additionally special design aspects that scale the necessary waterway dimensions in inland areas have to be considered such as the strong influence of cross flow or the visibility conditions. So, a new design method will be recommended, especially for fairway width in canals and rivers, bridge openings, diameters of turning basins or the length and width of lock approaches. In so far eight meetings, two interim meetings on special questions, a workshop within the framework of the Smart Rivers Conference last year and several internal workshops, the group finished the review of existing guidelines. It analysed several best practice examples, especially concerning fairway design in rivers, the dimensions of lock approaches and bridge openings. Presently a first draft of the future guidelines will be worked out, basing mostly on the contributions to the Smart Rivers Conference 2013 and the present paper, which includes these papers with some additions according to the agreements of the last meeting in February of this year. So, the paper provides information on the working group process and the actual findings. In more detail, the three recommended design steps: "Concept Design Method", "Best Practice Approach" and "Detailed Design" will be demonstrated by examples. As for all design cases the existing, possible future or necessary safety and ease of navigation conditions have to be assessed or defined. For this WG 141 provides planners with an appropriate approach, depending on the ship type, ship speed and traffic density as well as the local boundary conditions to be considered.

1. INTRODUCTION

One of the motives for founding PIANC-INCOM WG 141 "Design Guidelines for Inland Waterways" was the lack of internationally accepted guidelines for inland waterway dimensions, in contrast to regulations for sea-going ships. So, there is a need for adequate new guidelines, especially on minimum horizontal dimensions of fairways, lock approaches or bridge openings, to support several new waterway improvement projects. Another reason to update existing knowledge of waterway design corresponds to the change in fleet, especially with an increasing part of longer, wider, deeper going and stronger powered vessels and consequently the dimensions of the design vessels. These new vessels are generally the reason why wider lock chambers, lock approaches and fairways are needed. On the contrary, these new vessels are generally better equipped than traditional vessels, e.g. with two thrusters instead of one, with twin rudders instead of single ones or with bow thrusters and passive bow rudders in some cases. This development, combined with a general reduction of the number of ships sailing on inland waterways, provides an opportunity to restrict the lateral dimensions of the navigation channels despite the larger widths of the vessels. Also new and better information

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services are available on the basis e.g. of GPS, ECDIS and AIS. Additionally, ongoing improvements in updating bathymetry data, better forecasts of hydrological conditions and the numerical modelling of rivers provide more detailed information about local velocities. This can possibly lead to more and more vessels, steered by an autopilot in the future, helping to exploit existing or restricted waterways as much as possible.

In contrast to sea-going ships, sailing with inland vessels is generally less dangerous, e.g. contacts with bank protections are more or less a normal situation when travelling in inland canals. This may be acceptable because of the lower ship speeds and the very much lower mass of inland vessels – and thus the very much lower kinetic energy of inland vessels compared to sea-going ships. If one takes as example a typical sea-going vessel speed of 12 knots (about 22 km/h), used in the report of MARCOM WG 49 about Harbour Approach Channels (PIANC 2014), defining the threshold to account for an extra width by speed, compared to 13 km/h for an inland vessel, which is the minimum achievable ship speed on the Rhine to be approved, and assuming that the mass of the largest sea-going vessels is 10 ten times higher than the largest inland push tow units, one ends up with a factor of ca. 29 between the kinetic energy and thus the possible damage potential of sea-going to inland design vessels. Additionally, the propulsion and rudder forces respectively, related to vessel mass, are about 4 times higher for inland vessels than for sea-going ships. In combination the reaction times of the largest sea-going ships are at least about 6 times slower than of inland vessels. This means that the damage potential is very much lower for inland vessels and the capability to avoid damages is higher because of better steerability. Hence, the standards for sea-going vessels, as described e.g. in the a.m. MARCOM report, should be higher than for inland vessels.

This can be demonstrated applying the MARCOM approach for straight channels without significant cross wind to inland vessels with the following assumptions: good manoeuvrability, relatively slow ship speeds (< 8 knots), sloped banks, smooth and soft bottom and ratio of water depth d to draught between 1.25 and 1.5. This leads to a minimum channel width (in keel plane) of about 2.2 up to 2.4 times of the vessel breadth B in case of one-way traffic, depending on the navigational aids (excellent or good) and to 4.8 up to 5.7 B for two-way traffic, depending again on navigational aids and the traffic density (light up to moderate). These numbers are larger than the recommended values of WG 141 for straight canals of about 2 B for one-way and 3 to 4 B for two-way traffic, depending on the chosen ease category. The differences between MARCOM approach and WG 141 are greatest in case of two-way traffic because of the very much higher damage potential in this manoeuvring condition for sea-going ships than for inland vessels. Another reason for the differences is the fact that inland vessels may be convoys with their variety of lengths to breadth ratios L/B , whereas sea-going vessels are mostly single ships with a less varying L/B because of hydrodynamic reasons. This in turn justifies the use of B as the only important scaling parameter for channel design for sea-going vessels with some exceptions, e.g. the extra widths in curves. By contrast waterway dimensions for inland vessels may vary e.g. on L/B too. Hence, the report of MARCOM WG 49 about Harbour Approach Channels is generally not appropriate for inland waterways, but for comparison reasons it is helpful for future guidelines for inland vessels in case of high necessary ease demands to define upper limits of channel dimensions, or to find out differences between two design cases as with and without cross wind.

Lower ease standards compared to sea-going are also demanded for because of environmental aspects, especially the Water Framework Directive in Europe, or climate change effects on free-flowing rivers might force planners and operators of waterways to narrow fairways or to increase their distance to ecologically sensitive areas. These constraints generally affect the safety and ease of inland shipping. All these aspects show that there is a need to specify the minimum necessary requirements on waterway dimensions, especially from the nautical point of view. This does not mean that WG 141 proposes these minimum dimensions. In contrary: looking on the aspects of safety and ease of navigation and the operational economy of shipping, the design should be generally as generous as possible, but, looking especially on impacts on the environment, socio-economic aspects or the politico-economics of the waterway improvement, the design should be as narrow as necessary – but not more than that. So, it makes sense to define just these lower limits to avoid needless discussions with opponents of waterway improvement measures and to look on the nautical aspects

only. This is the main task of PIANC-INCOM WG. But because adequate minimum dimensions are strongly dependent on the local boundary conditions, the nowadays usual and generally accepted design approach, which will be called in the following “Concept Design Method” and which is the basis of existing guidelines, fails in cases where the special aspects to be considered are far away from the design cases covered by the guidelines and when the application limits of existing design formulae are reached. Some of the special aspects are listed below:

- Fairway conditions (curvature, depth, navigable width, flow velocities and their direction, turbulence, water level slope, bank course, training structures etc.).
- Hydrologic conditions and weather (visibility, wind, raising or falling stage, low or high water).
- Vessel type, steering and instrumentation (with or without bow thrusters, single or twin rudders, one or two-wheeler, powering, Radar, GPS, ECDIS, AIS, auto piloting).
- Actual or aimed load and speed (deep draught, empty/ballasted, cargo type, fast or moderate ship speed).
- Driving situation and traffic (one- or two-way, meeting, overtopping, weak or strong traffic).

Therefore WG 141 proposed a three step design method (Söhngen, Rettemeier, 2013b), which will be explained in chapter 4. Because this method contradicts somewhat to the terms of reference defined from INCOM, a brief discussion about the decisions of WG 141 concerning this point is given in the following chapter 3 (Söhngen, 2013, Söhngen & Rettemeier, 2013a). The last proposal to account for safety and ease of navigation aspects in the future report will be shown in more detail in chapter 5, because it affects all the design cases considered. The paper finishes with an outlook on further and ongoing activities of WG 141.

2. DISCUSSION OF THE TOR

According to the assignment of the PIANC inland commission from June 2009 (terms of reference, shortly TOR), WG 141 should “undertake a review of current papers, data sources, current research and experience relating to the design of inland waterways and prepare a PIANC publication giving guidelines to aid designers, developers and operators of proposed and existing inland waterways”. The report shall “consider all the major issues associated with the dimensional constraints associated with the passage of vessels along river or canal channels for both commercial and leisure use”, taking into account e.g. effects of “visibility, current, wind, cross flows and speed of vessels”. The recommendations shall focus on the “size of fairways, sweep of bends, lock approaches” and “size of bridge openings”. This comprehensive demand of INCOM was discussed controversially during the first meeting of WG 141. According to the experiences of WG 141 members, the actual importance of a steadily changing fleet and facing the possible performance of a working group in a restricted time schedule, the group decided to focus on commercial navigation.

The TOR demand next for “considering the actual dimensions of vessels as determined by already agreed standards such as CEMT, UNECE, USACE” and “to formulate” corresponding “channel and infrastructure dimensions”. This was not put into question, because most of ongoing projects are associated with the improvement of navigation channels for these new standards. The WG “should consider” also “the use of single and two-way working of channels associated with density and supervision of traffic which will promote the economic development of waterways that are marginal either in terms of size or use”. Also “current research and papers dealing with Climate Change and the minimization of the environmental impact of vessels on a channel ecosystem” shall be “considered in the review of channel dimensions. Reference to mitigation measures for flood and drought should be considered if at all possible although it is recognized that there is considerable ongoing research which may preclude any conclusions being drawn at the current time”.

The WG members didn't see that these extensive tasks could be fulfilled in a limited time schedule. But it may also not be necessary in case if technical minimum limits of waterway dimensions will be defined, considering necessary safety and ease of navigation standards. In this case the demands of an economic, ecologic and hydraulic engineering acceptable design will be accounted for to some extent automatically, because the approach avoids under- or overdesign. And one can avoid needles

discussions about the way and extent of foreseen waterway improvement. So, WG 141 will focus on technical aspects and safety and ease of navigation demands only. This means, in particular, that WG 141 does not put the waterway improvement measures proposed into question. These are generally a result of intensive economic and environmental studies and are therefore outside the scope of WG 141 recommendations. These studies define also the corresponding vessels to be considered. But important nautical design aspects that could in turn affect the improvement measures in general and so the planning standards have to be discussed in the recommendations, as e.g. the necessity of two-way traffic or the choice of appropriate safety and ease of navigation conditions. Also an appropriate approach to consider all the relevant design aspects, starting from the clarification of the design case, the choice of relevant boundary conditions to be considered, the selection of appropriate design methods, the performance of the design and the check of impacts and drawbacks to the improvement measures in general and to the a.m. points in particular, leading to a refined design if necessary, shall be handled in the future guidelines, see chapter 4.2. But specific numbers, e.g. of necessary minimum lock approach lengths, will be given taking nautical aspects on necessary waterway dimensions only!

Hence, the future recommendations of WG 141 take the agreed measures generally as a given boundary condition for the nautical design, but it gives nevertheless guide notes on what could be the drawback on the planned measures. So, the future recommendations of WG 141 give neither recommendations at all, whether a waterway improvement is necessary or not, up to which extent it will be acceptable e.g. from ecologic reasons or which ship type may be more appropriate than the chosen ones, WG 141 report just shows onto necessary waterway dimensions in the sense of cause and effect relations and from the nautical point of view only. The reason of this restrictive approach is not that the group members wouldn't be able or willing to give more comprehensive answers (the WG members are often faced with these questions in their professional work), but there will probably be no chance to get the recommendations balanced with PIANC members and even an agreement within the working group maybe complicated. Hence, all the design aspects mentioned before have to be handled outside the future report. Nevertheless, the report will give enough information and feedback to the planning process even if it will be limited to nautical aspects.

INCOM made also reference "to all current and relevant PIANC reports". Special attention should be drawn to MARCOM WG 49 and its report on Harbour Approach Channels (PIANC, 2014) for sea-going ships. This reference generated a discussion about the applicability of the corresponding MARCOM approach, which provides a table about necessary minimum dimensions e.g. of necessary minimum fairway width plus increments to account for special effects as wind, cross flow or bed roughness on the design, see application example in chapter 1 of this paper. The discussion ended as stated earlier, to use the MARCOM approach as a basis for the proposed Concept Design Method for inland navigation, but for special design cases only and clearly with somewhat other numbers concerning the necessary minimum waterway dimensions. Generally WG 141 recommends the above mentioned three steps approach, especially to account for the huge variety of boundary conditions in inland navigation compared to approach channels. This variety could lead to the assessment that standards for inland going vessels maybe hardly to define, especially facing the different ship types all over the world. However, from morphologic and hydrologic reasons, especially the depths in large inland waterways, which scale the maximum draught of the vessels, are more or less the same to be about 2 – 3 m, and taking structural demands to construct ships made of steel, maximising cargo volume and so blockage, lead to corresponding breadth of a single vessel and therefore to comparable breadth even for different rivers all over the world. This, together with the variety of draughts at different water stages and the need to sail in rivers with strong cross currents and narrow curves, led to similar ship constructions in size, installed power, and type and number of rudders. This in turn makes a standardisation possible, even if there are much more effects to be accounted for than for approach channels for sea going ships. In summary the group decided

- To focus on inland-going freight vessels,
- To review guidelines and extract recommendations supporting the Concept Design Method,
- To collect and discuss practice examples as the second design basis if available guidelines do not handle the special design aspects to be considered,

- To give guidance on the general design approach, considering e.g. the clarification of the design case, the choice of relevant boundary conditions, the selection of appropriate ease of navigation categories and the drawback of the performed design on the planned waterway improvement,
- But to focus on nautical aspects only and to accept the predetermined general improvement strategy as constraints for design, as well as
- To perform generally a three step design, starting with a Concept Design, Best Practice and end up if necessary with a Case by Case Study using simulation techniques if necessary.

3. UPDATE WORKING GROUP PROGRESS

The kick-off meeting took place during the PIANC Congress in Liverpool in 2010 (see also table 1, where some important information about the working group's progress is collected). The discussion about the terms of reference issued by INCOM in Liverpool and the next meeting in Karlsruhe, showed that the group probably cannot fulfil all of the requirements. It was decided e.g. to restrict the work to freight vessels and technical aspects and to neglect recreational boating in a first step. The detailed review of existing guidelines concerning these topics which followed during the next two meetings in Brussels and Paris, showed some huge differences, e.g. concerning appropriate minimum waterway dimensions or length of lock approaches, between the lower limits set in German or French guidelines or between the upper limits of Russian or Chinese guidelines, for instance. Besides the guidelines, existing dimensions e.g. of fairway widths in rivers are totally different from country to country or river to river. Thus, the group had to face these special boundary conditions, e.g. narrow canals, low ship speed, very well equipped vessels and optimally trained helmsmen delivering arguments to accept a reduced standard in some cases. On the other hand, large sea-going vessels, sailing with high speed on the large rivers of China, causing a higher risk level, will force planners and operators of these waterways to demand for higher levels of safety and ease. The group decided to explain the huge differences in its design recommendations and to collect arguments for choosing an appropriate design standard from case to case. This may help to align the different guidelines.

The group began to identify appropriate minimum dimensions of canals during the next two meetings in Brussels and Bonn. The widths, depths in straight reaches and corresponding vertical and horizontal clearances of bridges, diameters of turning basins or the lengths of berthing places were derived from existing guidelines and best practice examples. The group members found out that it is possible to recommend specific numbers, e.g. the appropriate width in terms of ship's beam, corresponding to ease of navigation categories which are mostly dependent on traffic density or the consideration of extra effects as wind in inland or coastal areas. The WG group called this approach "Concept Design Method", which may be used in standard cases with defined boundary conditions.

Only a few guidelines, e.g. from Russia or China, provide detailed information about appropriate waterway dimensions for rivers, e.g. the minimum width of lock approaches in case of significant flow velocities. Seeing that every river can be unique regarding its nautical boundary conditions, general recommendations may fail in special conditions. The group decided to recommend a detailed design in these cases during the meeting in Madrid. This method may be generally acceptable as the costs of a detailed nautical study are only a little fraction of the construction costs – and the study can reduce the latter significantly. The group therefore discussed the possibilities and restrictions of modern simulation software – and what should be the necessary inputs and results of simulations.

Appropriate safety and ease of navigation standards are hard to define, and since safety and ease will change waterway dimensions significantly, the group decided to recommend, besides the "Concept Design" and "Case by Case Design", an approach based on best practice examples. Here the group collected and discussed numerous data during the meetings in Utrecht and Antwerp, e.g. existing fairway or lock approach dimensions, to define the corresponding boundary conditions and to give comments about practice experience. Thus, the user, taking the "Best Practice Approach", is able to compare his special boundary conditions with the existing examples and will be supported to find out

appropriate dimensions for his special design cases. If there is a wide spread in existing data, he is able to find arguments to perform a detailed design study instead or additionally.

No.	Year, Location	Main topic	Main results
1	2010, Liverpool	Subject and TOR, general approach	Start review existing guidelines
2	2010, Karlsruhe	Table of contents	Commercial vessels only
3	2011, Brussels	Collection of existing guidelines	Definition of design vessels
4	2011, Paris	Review existing guidelines	Need to consider safety & ease
I1	2011, Brussels	Workshop planning	Best practice in rivers instead of using guidelines
5	2012, Bonn	Fairways in canals, rivers, bridge, turning basins	Dimensions for concept design method in terms of ship beam
I2	2012, Madrid	Application of ship handling simulators	Need for case by case design, especially for locks
6	2012, Utrecht	Fairway rivers, turning basins, berthing places	3-step design, best practice fairway rivers
7	2013, Antwerp	Discussion on safety and ease, lock approaches	Lock approach dimensions, turning basins
I3	2013, Maastricht	Workshop Smart Rivers	Positive feedback to the approach, especially concerning narrower standards
8	2014, Brussels	Findings Smart Rivers Conference 2013 (SRC)	Agreement how to involve SRC papers in the report, responsibilities to each chapter

Table 1: Overview of meetings of WG 141 with main topics and decisions (“I”=interim)

The interim meeting at the SMART Rivers Conference (in the following shortly “SRC”) in Maastricht and the positive feedback to WG 141 workshop showed that the working group is generally on the right way, but that the choice of the terms of reference considered and the main differences to MARCOM approach should be commented as outlined above. Therefore, it was decided to use the conference papers as a basis for our future guidelines. The workshop showed clearly that the three steps approach, providing process recommendations in many cases instead of giving specific numbers, is very helpful, especially to ensure that a detailed study using simulation technique, delivers appropriate results or those on the safe side. Nevertheless, the participants demanded for as many values concerning waterway dimensions as possible. Also the approach to account for safety and ease of navigation demands using three ease categories and the appropriate assignment of these categories to the Concept Design values were generally supported. This approach corresponds to the demand of several participants for “more realistic” or generally narrower standards as those for sea-going vessels, if one takes the values of the ease category C. But the discussion showed further that we need more practice examples are necessary, especially for fairways and lock approaches in rivers.

During the 8th meeting in Brussels in February 2014 the results of the SRC were reviewed. The working group came to some agreements concerning the minimum water depth at lock approaches, accounting for the efficiency of usual bow thrusters, the layback of berthing places in rivers with significant flow velocities, the sight distance at junctions and the way how to present practice examples. The ongoing discussion about defining appropriate safety and ease of navigation standards ended in a modified approach, outlined here in chapter 5, taking two new criteria into account: recreational boating and speed range and avoiding the designation “standard” or “level” using “category” or “score” instead. Because the safety of navigation should be ensured in every case, the working group decided to look on the ease of navigation aspect only. It was also decided how to involve the SRC papers in the report. A 1st draft of the report, basing on these papers and the assignation of these new categories to the Concept Design values will be the task of the 9th meeting.

4. UPDATE GENERAL APPROACH

4.1 General Approach

Referring to chapter 3, the group decided to recommend generally three steps in design, which will be explained in more detail in the following. But one has to specify all the relevant design aspects before

and if necessary after the design has been performed again to account for possible drawbacks on the design case or generally the planned waterway improvement. This general design process is illustrated in figure 1 and will be explained in more detail in the following:

(1) To clarify the design case look on existing and future fleet, accounting for the aimed lifetime of the design measures, define from this the design ships with its typical draughts (generally a fully loaded and an empty vessel) and heights above water table (maybe different numbers of container levels has to be taken), the traffic situations to be considered, mostly meeting or single drive of the largest vessels going upstream and downstream, taking into account especially the traffic density and possible waiting times in front of bottlenecks and so on. Appropriate check lists concerning important aspects and necessary data should be part of the future report. They are depending on the design stage, indicated by the boxes in figure 1, but also on the waterway dimension considered, e.g. the fairway widths in a free flowing River.

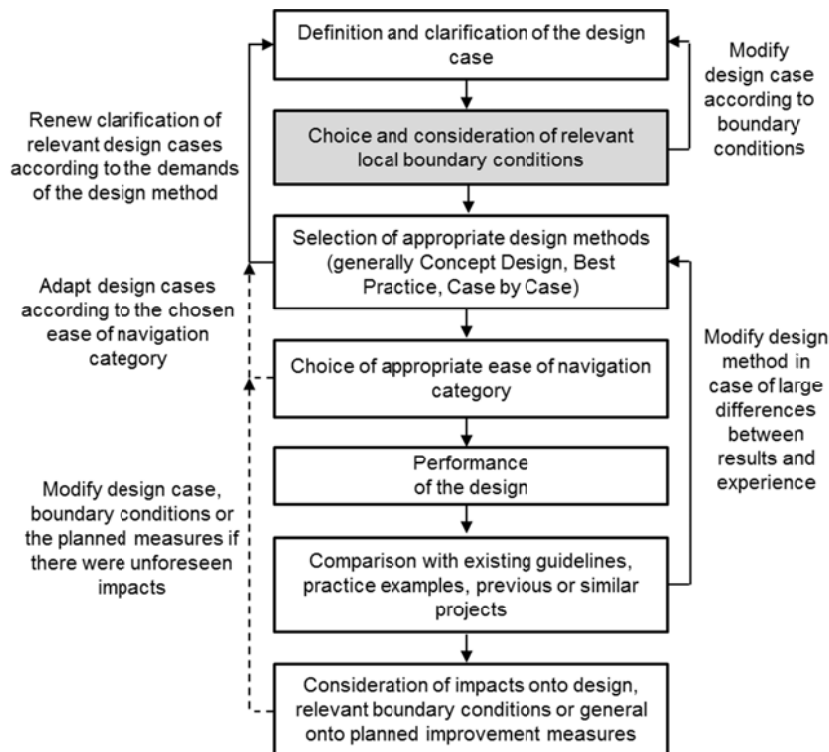


Figure 1: General approach and steps to follow for designing inland waterway dimensions

(2) Look at local boundary conditions as the probability of strong crosswind and bad visibility conditions as fog, the variety and probability of occurrence of different water stages with its different flow velocities, especially longitudinal currents for ships sailing downstream in narrow curves or approaching locks from upstream and cross currents at outlet structures or in front of lock approaches. Look also at ship induced impacts in general and especially at the stability of banks (aspects excess pore water pressure and erosion rate) and at ecologic sensitive areas to be spared, defining necessary minimum bank distances that maybe larger than navigational safety distances. Modify design case according to boundary conditions if necessary. Again use corresponding check lists for relevant aspects and data (to be provided in the future report of WG 141). One example concerning the local boundary conditions to be considered in case of the analysis of the fairway conditions in a free flowing river is given in table 2. Even if the check list is not complete, it demonstrates the complexity of the design problem, the partly huge number of necessary data and so, the need to simplify the design problem or concentrate on the design relevant boundary conditions.

(3) Select an appropriate design method, e.g. use national guidelines (Rettemeier 2013), if they treat the design case considered (then the design process may end up here), use appropriate other guidelines or follow the three step design process as recommended herein, taking into account the constraints and demands as described in the following chapter. If necessary, review the specification of the design case and the boundary conditions considered according to the design method chosen.

aspect	boundary condition	data or information needed
fairway con- ditions	relevant water stages: generally low and average stage, stage with full draught (min. navigable width), highest permitted stage (largest swept area width, but more space), stage at which parallel dykes or groynes will be overtopped (cross flow, stages where banks and sensitive areas may be affected)	calculations or measurements (at least 2D) concerning flow field, water table, including longitudinal and sideways slopes, bathymetry with training structures and banks, on occasion of high stages with flooded plains
	theoretical and real course of the fairway boundaries, including positions of buoys, radar marks and usual landmarks for nautical orientation, usual points for making critical manoeuvres as overtaking	survey of ship courses, e.g. by analysis of AIS data, inquiry among ship pilots and water authorities, ECDIS charts
load and speed	water stage depending maximal and average draughts of full loaded vessels, reach dependent risk of grounding	local loading rules at relevant gauges, river bed granulometry, areas with rock outcrop,
	hydrodynamic maximum possible (critical) ships speeds for different vessels, draughts and stages at each relevant cross section, usual ship speed or power used	return current relevant (effective) cross section areas, including water depth at ship path and flow velocity
hydro- logy and weather	visibility conditions, wind influence	days with fog, wind statistics, including direction and probability of wind speeds, possible shading e.g. by trees
helms- men	reach specific experiences, skills, training levels, average journey times in the reach considered, attention level, stress, distraction	strictly confidential dialogue with pilots, inquiry among ship pilots and waterway authorities

Table 2: Check list (incomplete) concerning the analysis of existing fairway widths in a free flowing river for the design step “boundary conditions” (grey box in figure 1)

(4) Choose an appropriate ease category (Deplaix & Söhngen, 2013), depending e.g on ship speed and traffic density. Modify design case if necessary according to the demands of the chosen category.

(5) Perform the design. Use more than one method, if there are doubts about the proper method.

(6) Compare the results of the design (if necessary using all the three recommended methods) with those of similar projects. If there are big differences or if there are special parameters, which influence the results more than expected, perform a sensitivity analysis concerning these parameters. Modify or refine the chosen design method(s) and corresponding relevant data in these cases.

(7) Check possible impacts on the design case and the relevant boundary conditions to be considered. Look especially at the stability of the bank slopes and buildings along the waterway and corresponding mitigation measures, possible negative effects on the environment, on water levels (especially increase of high stages), expenses for mitigation measures or unforeseen socio-economic impacts, if e.g. the designed waterway dimensions are very much larger than expected. In these cases, go back to modify the design case, e.g. concerning the traffic situation (one-way instead of two-way) and contact your client concerning possible modifications to the planned improvement measures. Take note that the design process is normally a closed loop, where all the steps, mentioned above and in figure 1, have to be run through several times. In case of a planned situation, this could include new hydraulic calculations concerning the flow field.

4.3 Concept Design Method

This design approach is generally the same as if existing national guidelines will be used (Rettemeier 2013, Söhngen & Rettemeier 2013b). The latter reflect the special demands for waterway use and improvement of the country, especially accounting for the national fleet, the tradition of shipping, the

politico-and socio-economical boundary conditions and the national and international laws to be considered. National Guidelines correspond therefore with generally accepted waterway standards and best practice in this country and are therefore the first choice for design. But, besides possible application limits of all the guidelines, e.g. concerning the design of fairways in rivers with significant flow velocities (Söhngen and Rettemeier, 2013a), there are also some general disadvantages in using guidelines: The first is that guidelines will be adapted often too late to account for new developments e.g. of a changing fleet. Hence, they are sometimes backward looking and they may hinder or hold back necessary developments. Because, as mentioned before, generally also not all relevant design aspects will be treated in the guidelines, this fact may narrow possible innovation and hinder adapting solutions to locally different boundary conditions.

But even if one has a broader view, taking not only the national guidelines, but taking also e.g. the Chinese or the US Guidelines to design fairway width in rivers, to stay with the same example, one could be confused, because there are partly huge differences in recommended special waterway dimensions, e.g. the length of lock approaches. These may be caused e.g. by different safety and ease of navigation demands or by different ship types, to mention just two aspects. So, taking existing guidelines alone does not solve the design problem in many cases.

For this reason, WG 141 proposes

- To look into national guidelines for all design cases covered by these guidelines first,
- To compare with applicable international guidelines next, in order to have an idea about the uncertainty of the demanded waterway dimensions next,
- To compare also with the extract of the review of existing guidelines (Rettemeier 2013),
- To take the corresponding recommendations of WG 141 for special design cases as necessary minimum width and depth of canals, bridge openings, length and breadth of lock approaches, diameter of turning basins or length and layback of berthing places, and finally
- To extend the design if necessary, using adequate formulae for so-called “increments”, e.g. concerning the extra width in curves in case of significant flow velocities or to counteract wind forces or cross currents from applicable guidelines or relevant publications.

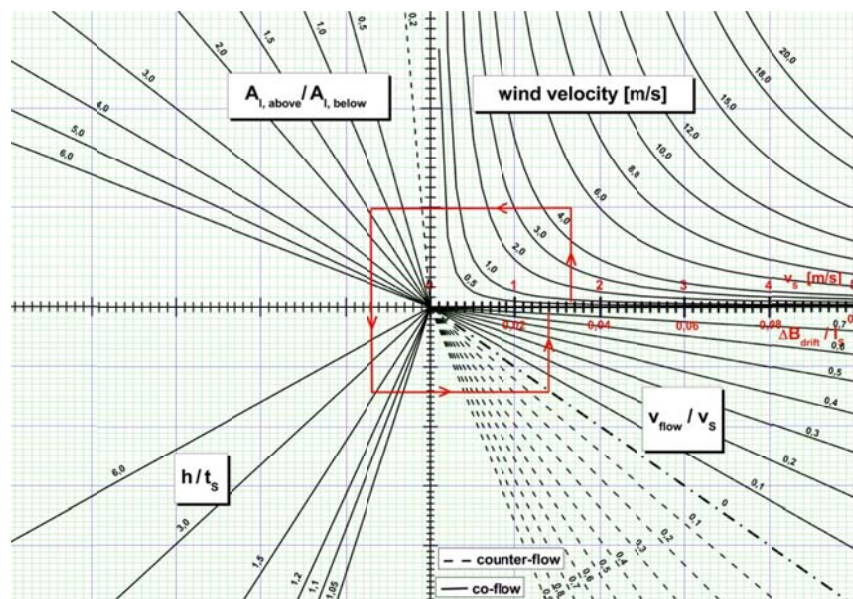


Figure 2: Design chart for estimating cross-wind influence on a Class Va vessel in a canal

This more comprehensive Concept Design Approach was demonstrated in our workshop at the Smart Rivers Conference 2013 (Söhngen & Rettemeier, 2013a, 2013b, Eloot et al. 2013). Additional formulae e.g. to account for the extra width in curves and those from the general instability of the ship’s course and human-factor-effects as well as a drive close to groynes were derived for supporting

a traffic simulation model for rivers, but they can be used for improving the Concept Design Method as well (VBW 2013, Fischer et al. 2014). But they can support the detailed design too, e.g. to specify the design case. It is for example very expensive to carry out simulations for all possibly relevant wind directions and wind speeds. By contrast it would be more effective, to find out some relevant wind situations instead. For this purpose one can use well known formulae to calculate the crosswise forces and moments caused by the wind attack, that have to be counteracted by forces on the underwater body of the drifting vessel, to have a good estimate about the extra widths to sail against the wind. This was done in the design chart of figure 2, using the boundary conditions of the German Havel Oder Canal (HOW). It applies to Class Va vessels without using a bow thruster and can be used, together with information about the existing fairway widths, e.g. to specify the permissible wind speed for exceptional transports, because the HOW is designed for Class IV vessels only. So, if one is forced to perform a detailed study using a ship handling simulator e.g. to clarify the specific conditions for admission of special transports in a canal, one can check in advance, whether the wind influence is relevant or not, or one is able to define the relevant wind situation. This will reduce the necessary number of simulation runs in the simulator. Concerning this design aspect, we decided to simplify the approach behind figure 2 for the future WG 141 report and to match it with the Dutch guidelines for canals.

4.4 Best Practice Approach

Only little information is available in existing guidelines regarding waterway dimensions in rivers. This concerns e.g. the lengths and widths of lock approaches or the necessary fairways in rivers. If, for instance, a new lock is to be designed or an existing lock approach has to be adapted to larger vessels (as in parts of the German Neckar river, which will be upgraded from 105 m long vessels to accommodate vessels of up to 135 m length in future), existing guidelines provide only limited information on how the length (from mole tip to lock entrance) and the entrance width of the upper and lower harbours have to be enlarged to accommodate a longer design ship with significant flow velocities. These enlargements are generally indicated, especially because of the wider swept area width of longer ships in the strong cross currents in front of harbours and the need of an adapted length with reduced flow velocities inside harbours. But these information gaps can be closed by looking at practice examples of lock approaches in rivers. The task is to find out existing examples that are comparable to the unique design situation considered (Koedijk 2013). The problem is that conditions can differ considerably from case to case, especially concerning existing harbour lengths. Examples are the German rivers like the Main and the Neckar. Constructed harbour lengths are between 0.7 and $2.0 \cdot L$ (L = length of the design vessel) on the Neckar River, with an average of $1.5 \cdot L$. The upper harbours on the Main River are on the other hand generally longer, from 1.4 up to $4.2 \cdot L$, with an average length of about $2.5 \cdot L$. There hardly seem to be any compelling reasons why one specific lock harbour is so much longer than another one. But one of the main findings from this wide spread of existing dimensions is that planners of lock approaches probably tried to make the harbour length as long as feasible, in order to optimize the safety and ease of navigation standard – and accepted a lower standard if there was obviously no chance to realize larger dimensions.

Another important finding is that safe navigation seems still possible, even in case of very narrow conditions as in case of lock approaches on German rivers or the fairway widths on the free flowing Upper Rhine River or those on the Main River. This may be possible due to the very restrictive licensing of the corresponding vessels, demanding e.g. for efficient active bow thrusters and can be demonstrated by looking on relations between existing fairway width b_F and breadths of the largest vessels B (ordinate), which are allowed to sail at typical bottlenecks, drawn in figures 3 and 4 over a parameter (abscissa), which comes from the theory of extra widths in curves. They show that there are huge differences between these relations. The lowest correspond to the narrowest conditions on the Upper Rhine and Main and the largest to the Lower Rhine River. But even if there are very little numbers in straight reaches to be about 3 for one-way and 3 to 4 for two-way traffic, it is clear that this

fairway conditions offer not an easy drive. It may be necessary to sail with high attention and to use all the navigational means available.

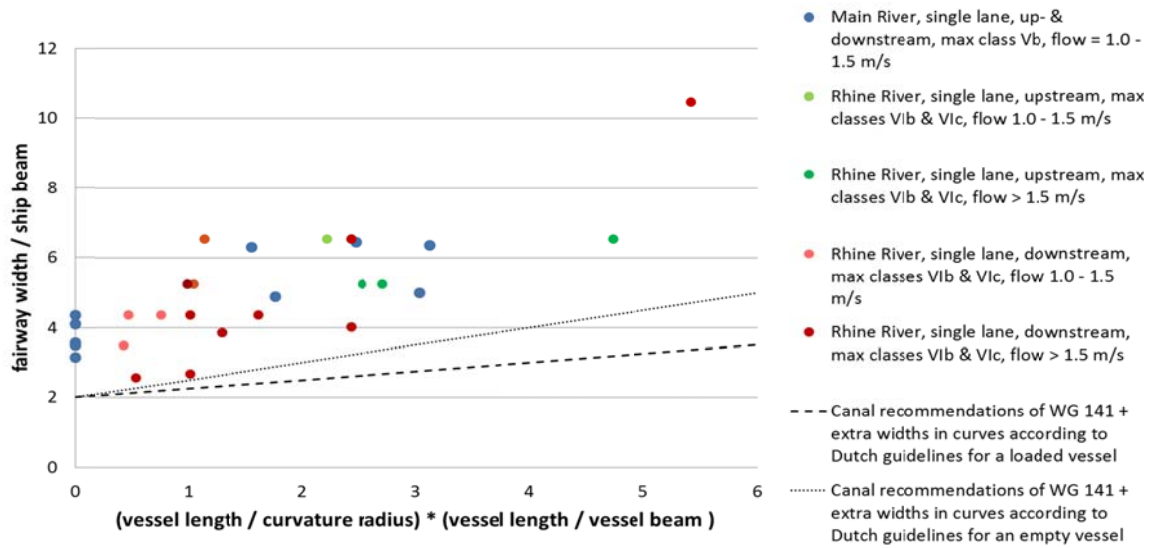


Figure 3: Existing fairway widths b_F of German Rivers Main and Rhine related to ships beam B at typical narrow reaches, data for largest permitted vessels sailing one-way, depending on the ratio of ships lengths to curvature ratio and flow velocities (the largest value reflects the special permissions in the Middle Rhine between Jungferngrund and Loreley)

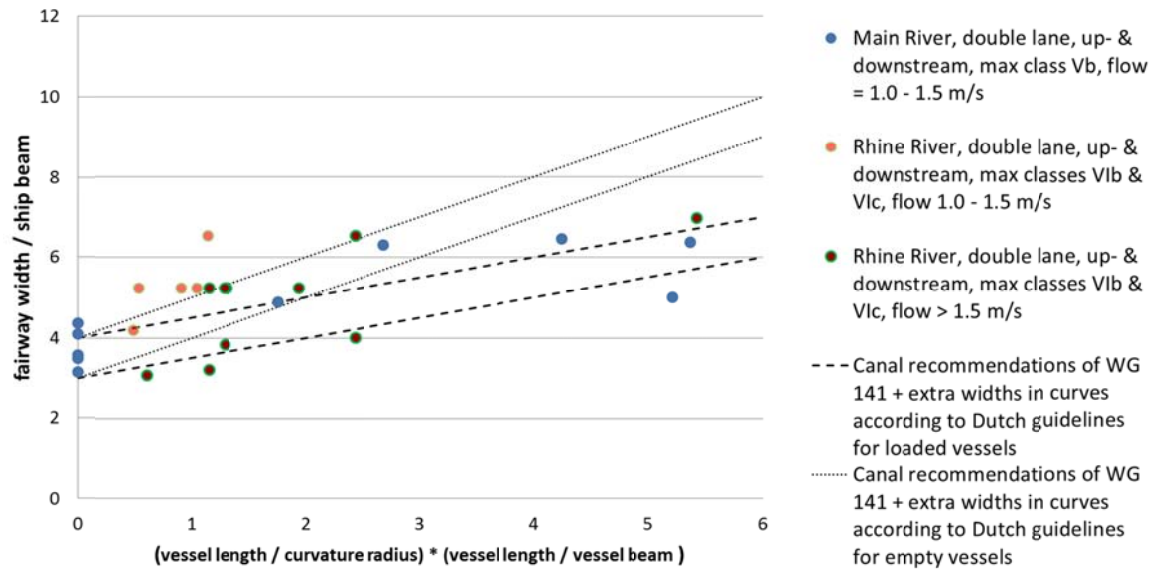


Figure 4: Existing fairway widths b_F of German Rivers Main and Rhine related to average ships beam B (up- and downstream) at typical narrow reaches, data for largest permitted vessels two-way, otherwise see Figure 3

But even looking on the smallest values of b_F/B in figures 3 and 4, they are bigger than those of canals. The latter are about 2 in case of one-way traffic of the largest vessels in small canals and 3 up to 4 for two-way traffic (without wind increments) in narrow or “normal” canals (Söhngen and Rettemeier 2013b), without curve increments. This means that there is generally a need for larger navigable widths in rivers than in canals, e.g. because of stronger influences of cross flows, turbulence, wind and also the orientation is generally worse in case of rivers compared to canals with

their clear bank lines. And there is another difference to be considered between canals and rivers: the data for canals include safety distances to banks (in draught depth), but the fairway data of rivers do not. Hence, the nautically usable width in rivers is still bigger than the “official” fairway width. Also another important conclusion that can be drawn from figures 3 and 4 is that there is a significant influence of the curvature of the river on the necessary fairway width. This can be shown even in case of constant fairway widths over long reaches as from the Rhine, because the permitted vessels are smaller in case of a narrow curve as it is the case in the Middle Rhine Reach near the Loreley Rock than in more or less straight river reaches. It should be noted that the exploration of practice data is not yet completed in WG 141. Other data as those from the Yangtse in China, the Rhone in France or the Mississippi in USA have to be worked out accordingly.

4.5 Detailed Design

The examples of existing harbour lengths or fairway widths demonstrate impressively the partly large range of uncertainty regarding appropriate waterway dimensions. Hence, when the spread of data from different guidelines or (best) practice examples seems too large, instead of specifying any additional values provided by WG 141, e.g. averages of multiples of L and B for harbour lengths and widths, a detailed study for the design case under consideration seems to be necessary. The criteria for cases where a detailed study (left column) or ship simulation software (right column) seems to be adequate for performing the Detailed Design or a Case by Case Consideration, are listed in table 3.

need for performing a detailed study for design	ship simulation techniques needed
design problem is not within scope of existing guidelines or experience	vessel has special properties, e.g. type, propulsion, steering
difficult layout like sharp or sequential turns, narrow width, variable depths, junctions, lock approaches, bridges, turning areas, berths	large discrepancy between space available and navigation needs
environment plays an important role, e.g. intense or variable longitudinal or cross currents, visibility, turbulence, water level variations	significant construction cost savings seems possible through optimization of engineering works and designs
to define operational limits or to accept higher operational limits	when evaluating risk-based design and traffic management
doubts about using a lower standard	training of captains to fulfil standards
human factor effects have great impact on design	to demonstrate the results and nautical aspects of design
accounting for high traffic density	considering special traffic or operations
to plan and check aids to navigation	to gain acceptance for navigational needs

Table 3: Criteria speaking for a detailed study (left column) and the use of ship simulation techniques (right column) in the design process

But even the best available simulation techniques may not be able to answer all design questions, because these techniques are only an approximation of reality, not reality itself, meaning that modelling inaccuracies are unavoidable. These can affect the design significantly especially in cases where ship induced currents and water level changes are dominant and influence the behaviour of the vessel, e.g. nearby a bank. Hence, adequate process recommendations to use simulation techniques are necessary and will be provided by WG 141.

Such process recommendations shall include:

- Examining whether a detailed design study or simulation techniques are necessary.
- Selection of the appropriate investigation method (bridge simulator, where a human being steers the ship; fast-time simulation, using autopilots to steer the vessels; traffic simulations, taking simplified driving dynamics or scale model tests).
- Choosing, collecting and appropriately processing the required minimum bathymetric, flow, construction and calibration data, especially for the design vessels.

- Calibration of the flow models and the parameters of the design vessels, taking field data or/and scale model tests and comparing them with simulation results, if possible having similar conditions as the design case.
- Validation of the models by performing runs to compare them with measurements that are not used for calibration.
- Conducting simulations, especially with respect to human factor effects, which may require taking different pilots with varying professional skills and personal fitness and many simulation runs for one variant, to account for random effects.
- Conducting adequate sensitivity analyses concerning critical design parameters.
- Statistical elaboration and interpretation of results, especially concerning human factor effects.
- Assess the application limits and unavoidable uncertainties of used simulation technique and the corresponding impacts on the simulation results and so, the necessary decisions for design.

This approach seems to be a critical point in the future guidelines of WG 141, because especially the providers and users of ship handling simulators tend to overrate the applicability of simulators just as clients of the navigational study tend to mix up real life and virtual reality in the simulator. Consequently, the use of simulation techniques needs some guidance as the process recommendations shown above, especially to account for the application limits of standard ship handling simulators, see table 4. Generally speaking, the limits are presently reached in the case of strong ship-induced currents and when the water level drawdown interferes significantly with the water body and with other ships. Future developments in the next decades may be able to overcome these application limits by simulating ship-induced currents and waves simultaneously with the ship motion.

Strong interaction forces (ship-bank and ship-ship) as in narrow canals.
Strong shallow water and canal effects, especially during overhauling
Strong bed roughness effects, e.g. on bow thruster performance or thrust
Irregular banks and long groynes
Strong water level longitudinal or crosswise slope
Drive inside lock chambers
Special problems, e.g. stones being sucked into propellers or ship-induced sediment transport processes like clouding, which are to be avoided in design case

Table 4: Present application limits of usual ship handling simulators

The application limits listed in table 4 do not mean that simulators totally fail in these cases, but simulation results should be interpreted carefully and used in a more or less *comparative* sense, as e.g. for hydraulic modelling. This “comparative thinking” in using simulators is worked out in more detail in table 5. It shows that it may be possible to extend the applicability of ship handling simulators with some modifications to the usual approach. The reason is that model errors eliminate partly, if the *difference*, e.g. of the calculated swept area widths of two variants, is the aim of the study. The need of “comparative thinking” in using simulation tools is one reason why INCOM WG 141 will provide process recommendations for the optimal use of ship handling simulators for waterway design purposes for inland navigation. According guide notes can be found in the MARCOM WG 49 report.

It should be mentioned that the Cases by Case Design may contradict the requirements of standardisation of waterway infrastructure, which is one of the methods to simplify the design processes, to support proved and sustainable solutions and so, to reduce construction and especially maintenance expenses. Hence, a Case by Case Design should always have the demands of standardisation in mind and maybe restricted to examine the application of standard-solutions in design cases far away from existing knowledge or experience.

Distinguish always the following two cases for each variant or aspect to be simulated:

Reference Case: This may be the existing situation or another well known situation, having the same important navigational boundary conditions as water depths, flow velocities or wind, draft, ship type etc., where many data of good quality are available, e.g. from field investigations or from existing experience, including navigational conditions with the aimed ease category for the design case, e.g. by taking data for a smaller vessel than for design, if the data come from a waterway to be improved.

Design Case: It includes all the relevant boundary conditions to be accounted for, especially the bathymetry, the flow field, the design vessel, but also the helmsmen with their usual training levels, attention etc., because reality may be different to the situation in the simulator environment.

Perform simulations for the *Reference Case* first and compare the results, especially concerning the relevant design aspect, e.g. the navigational space needed or the assessment of the pilots concerning the safety and ease of the navigational conditions. If there are large differences to the available data or experiences, renew the calibration of the models used or check, if there are unconsidered effects as different skills or fitness of the pilots in the simulator and the available data or better or worse sight conditions. If the differences may be acceptable, note that nearly the same differences may occur in the simulations of the design case.

Perform Simulations for the *Design Case* next and add the differences between simulated reference case and known data. These modified simulation results are more correct than the simulation results itself.

Use objective criteria for assessing the difficulty of a navigational condition considered as the number of rudder actions per unit time, the largest rudder angles needed, the amount of engine power used, the total time needed for a manoeuvre, the navigational space used or the smallest distances between vessels occurred or to waterway infrastructure as banks. The corresponding values can be used for the comparison between reference and design case and for adding the differences as shown above. Using specific numbers is always better than trying to rank e.g. the “feel” of a pilot during a critical manoeuvre by arguments only. Note that it is generally not sufficient that the helmsman “feels” that the simulations may be correct, e.g. concerning the behaviour of a modelled vessel, because the “feel” cannot be quantified.

Table 5: Principles to minimize modelling inaccuracies in waterway design by using ship handling simulators by “comparative thinking”

5. UPDATE APPROACH TO ACCOUNT FOR SAFETY AND EASE OF NAVIGATION

5.1 Reasons for defining different ease categories

The differences in existing and recommended waterway dimensions in national guidelines may be caused by the fact that, every waterway system, with its specific features, especially water depths and widths, flow velocities, average transport distances, economic conditions of inland waterway transport, cargo type and the tradition of shipping, forms its unique fleet from which the accepted minimum dimensions of waterway infrastructure can be derived. So, navigational and therefore the safety and ease of navigation conditions are definitively different from country to country or from waterway to waterway. Nevertheless, at least the safety of navigation should be ensured in every case. Therefore WG 141 decided to distinguish different ease categories only and assumes that the safety is guaranteed by permissions or design. But there are several objective criteria, why the waterway dimensions should be chosen more generously, e.g., if there is a great potential risk of loss of human life in case of damages. Otherwise lower standards may be acceptable in some cases too, e.g., if the usable or possible ship speed is poor, as it is the case in narrow canals. These criteria will be discussed in the chapter 5.2.

Based on these criteria, different ease “categories”, “scores” or “qualities”, as called now in WG 141 after a long discussion about the proper wording, will be defined. Before WG meeting No. 8 the word

“standard” or “level” (Deplaix and Soehngen 2013, Soehngen 2013 a) was used. The wording was changed, because the working group did not want to remove the responsibility from the user of the future WG guidelines to choose the right standard, e.g. according to those defined in national guidelines. The only aim was to give guidance in *assessing* the ease conditions in a specific navigational situation – which is called in the following the “analysis case” –, e.g. to be able to compare it to another driving situation or to an aimed category. In addition the decision makers must be supported with arguments to find out an appropriate category for the “design case”. Both interpretations – analysis and design case –, are necessary to assign the ease categories e.g. to practice examples and to specific recommended numbers for selected waterway dimensions. In the publications of the Smart Rivers Conference 2013 only the design case interpretation was considered.

5.2 Criteria for choosing appropriate or analysing existing ease categories

Scaling factors for waterway dimensions are depending on a large number of influencing parameters. These have an effect also on necessary ease qualities. If there are uncertainties to be accounted for, e.g. in case of possibly poor fairway conditions with strong, highly turbulent currents or irregular banks, or caused for instance by future adaptation measures to account for ecological demands, the design should be more generous than in case of traditional waterways. On the opposite, good information systems up to using autopilots, together with modern steering systems as bow thrusters, two strongly powered propellers and twin rudders instead of a single propeller or single rudder, can significantly reduce necessary waterway dimensions. This can generally be accounted for by the proposed Case by Case Design, using usually ship handling. But besides these more or less quantifiable design aspects, it may be necessary to choose larger waterway dimensions than usual in case of unforeseeable design risks. If, for instance, the fairway is foreseen for one-way-traffic only, because meeting or passing of vessels may be avoided by traffic management, the usable navigable space has to be designed more generously than in a channel for two-way-traffic, because, e.g. in case of bad visibility or strong wind, the wider fairway designed for meetings of vessels is generally still large enough for one-way traffic, but the fairway for one-way-traffic may be too small, if there is no extra space foreseen to account for special situations. Larger dimensions may also be necessary, if the amount of damages in case of accidents is high, e.g., if there are buildings, quay walls, groynes, rock outcrop, floating facilities such as floating restaurants and vessel berths besides the fairway. In this case, every steering error may cause a hazardous situation. In contrary, if there are sloped sand or gravel banks besides the fairway, steering errors may end up in bank contact, but without severe damages on the ship or waterway infrastructure. Also crashes with another ship can be avoided by sailing the ship onto the bank. So, necessary waterway dimensions are depending on the damage level in case of unforeseeable situations. These may be caused especially by human-factor-effects, e.g., if the helmsman, who is one of the most important influencing parameters in waterway design, is highly skilled, experienced and attentive, which leads to smaller acceptable waterway dimensions, or if he is poorly instructed, distracted or stressed, which requires more navigational space.

All the above mentioned aspects and some more (“*mixed criteria*”) are collected in table 7 as a *first rating group* to find out appropriate ease categories. A *second rating group* looks at the *vessel speed* in table 8 and a *third rating group*, collected in table 9 accounts for the *traffic density*, which is obviously linked to the necessary ease quality. For low traffic density e.g. the risks of accidents is very much lower than in case of high density and also politico-economic losses due to constraints in case of undersized waterways with high traffic are obvious and should be avoided. Analogous criteria can be found in several national guidelines and also in the report of MARCOM WG 49. All the three rating groups will deliver a more or less clear assignment of one of the three chosen ease categories, defined in table 6. It is the responsibility of the user of the future guidelines to weight the possibly different results of the three rating groups.

Looking on the speed criterion in more detail the findings are: in case of low speed, as in canals or in rivers sailing upstream, there is more time to correct steering errors or to react on unforeseeable situations than in case of high speed when sailing downstream a river at high stages. So, the higher

the possible or the permitted speed, the higher should be the ease category. This holds also true if the waterway reach is used for recreational boating to a significant extent, especially from rowing boats (restricted sight) or canoes (sensible to waves), to ensure the safety of the private boat pilots. But on the opposite, if the helmsman is *forced* to sail fast, e.g. downstream in a narrow curve of a free flowing river with high flow velocities, in order to restrict the extra width, if the vessel has neither passive bow rudders or thrusters, the necessity to drive fast is a criterion to assess the ease of the navigational conditions to be low. Therefore, the speed criteria should consist of three parts: speed value, traffic density (of recreational boating) and speed range. If the latter is generally high as in case of still water, the ease category is high too, but if there is only a narrow “speed window” to sail safe, as in case of a canal designed for one-way traffic, where the difference between the critical speed (where the stern wave breaks) and the minimum speed to ensure a usual reaction of the vessel on rudder actions is very small, as in German one-way-canals of about 2 km/h or less, leading to a low ease category.

5.3 Designation of different ease categories

But before trying to assess the navigational conditions according to such ease categories, one has to define and designate it. Looking for this purpose e.g. on the fairway conditions in the Lower Rhine River in Germany or the Netherlands, with fairway widths offering nearly unrestricted sailing conditions, even at high stages and for all permitted vessels, and compare it to narrow openings at historical bridges, as the “Old Bridge” of the German Neckar River in Heidelberg, where a safe drive is possible only if the helmsman is highly attentive and if the vessel is well equipped, one can assign the drive e.g. on the Lower Rhine to be a “nearly unrestricted” (designated by letter “A” in table 6) and the navigational conditions on the Neckar at the Old Bridge to be “strongly restricted over short distances” (designated by letter “C”). This designation was used in table 6 to specify two of three different ease categories. But why distinguishing exactly three and not two as the “normal” or “narrow” canal profile in the Dutch Guidelines or even more than three, which would allow for a better categorization? One reason is that WG 141 decided to neglect both the upper end of possible safety and ease standards - where all possible ships, even those, who are poorly equipped, can sail without interacting with each other and where also poorly trained helmsman can sail safe in the area considered, focussing as stated earlier on necessary *minimum* waterway dimensions - and the lower end of the standards, concerning all extremely restricted waterway conditions, forcing the helmsman to steer his vessel at strongly reduced speed, as during entry into locks or manoeuvring inside a harbour, looking on waterway dimensions that are scaled by a sailing vessel and not a vessel under manoeuvring conditions with extremely reduced speed. Looking again on the fairway conditions in European rivers, it seems appropriate to add another ease category between the extremes of Lower Rhine and Neckar, called ease score “B”. These are characterised again in table 6, together with some examples, to illustrate what they could mean.

ease score	designation	example from existing waterways
A	nearly unrestricted drive	Lower and Middle Rhine River for all permitted vessels
B	moderate to strongly restricted drive	largest permitted push tow units on the Mississippi River, Upper Rhine River, Neckar River, Dutch canals, normal profile, passing narrow bridges under good visibility conditions
C	strongly restricted drive on short distances	German canals or narrow profile of Dutch canals, narrow bridges under bad visibility conditions or strong currents, sailing at lock approaches

Table 6: Designation of ease standards with examples (still under discussion in WG 141)

5.4 Mixed criteria to analyse or choose appropriate ease categories – 1st rating group

Coming back to the approach outlined above to find out the ease category, several criteria must be matched altogether. For this, a scoring system will be used. It is based on the number of criteria or

arguments fulfilled. Only *positive* results will be used and can be managed by marking the box with the criterion fulfilled by an “x” or “y”.

- Looking for the *design case* first, an x-mark is used, if the argument in the box speaks for a higher necessary quality or a y-mark, if a lower category may be acceptable. The x-arguments are collected in the left coloured (warm colours) column of table 7 and the y-arguments in the right coloured (cold colours) column. It is obvious that the necessary ease category should be higher in case of many x-marks and few y-marks and may be lower if there are only a few x-marks and many y marks made. So, the necessary ease category is related to the numbers of x- or y-marks. These numbers are still under discussion in WG 141. The last attempt to find an agreement is shown in tables 10 and 11, where all the criteria to assign the mixed, speed and traffic arguments to an ease category are collected.
- Concerning the *analysis case*, an x-mark should be set in a box of the left warm-coloured column, if the navigational condition to be assessed fits with the facts described in the box that speak for low existing ease quality. So, the x-marks for the analysis case e.g. concerning the navigational conditions in a narrow waterway section, will probably be set in the same boxes as the corresponding design case, because a low existing ease score demands for a high ease quality in design, if the navigational condition should be improved.

criterion	“x”-arguments, defining a higher necessary ease score for design or a lower existing ease score	“y”-arguments, defining a lower acceptable ease score for design or higher existing ease score
	Design Case (DC): Mark the box with a “x”, if the navigational condition described in the box is true for design	Design Case (DC): Mark the box with a “y”, if the navigational condition described in the box is true for design
	Analysis Case (AC): Mark the box with a “x”, if the navigational condition to be analysed fits with the arguments in the box	Analysis Case (AC): Mark the box with a “y”, if the navigational condition to be analysed fits with the arguments in the box
1 type of load	deep draught vessels and dangerous goods	empty or ballasted vessels, no dangerous goods
2 level of training, personnel skills and experience	poorly trained pilots, low knowledge on waterway features and infrastructure	optimally qualified and experienced helmsman
3 attention level, distraction and stress of the helmsman	long time or boring drive, permanent manoeuvring conditions	short manoeuvre situation, e.g. during a meeting or by passing a bridge opening
4 danger level, possible damages	buildings, quay walls, floating facilities, vessel berths in the vicinity of the navigational area, danger of life and limb	sloped banks, guiding walls, parallel dykes or short groynes besides the fairway
5 uncertainty of waterway conditions	turbulence, secondary currents, irregular banks, long groynes, rocky or stony river bed, wind, fog	regular shoreline, sloped sand or gravel banks, low wind speed or wind protections
6 traffic situation, ship-ship and ship-bank-interaction	one-way traffic, many manoeuvres as overtaking	2 or more navigational lines, accepted interaction forces
7 vessel equipment and instrument-tation	main rudders only or weakly powered bow thrusters, sea going ships, low engine power, no information systems	strongly powered bow thruster or passive bow rudder, high engine power, dual propellers, optimal information systems
8 recreational boating	low recreational traffic, mostly motor boats	high recreational traffic, especially rowing boats and canoes

Table 7: Mixed criteria for choosing appropriate or analysing existing ease categories – 1st rating group

Analysing existing waterway conditions or recommendations in existing guidelines for the *design case*, it seems necessary to choose the highest ease score A in case of at least 5 or more x-marks or 2 or less y-marks. The category B may be adequate, if the number of x- or y-marks is between 3 and 4, and the lowest ease quality C may be acceptable, if the sum of x-marks is 2 or lower or the number of y-marks is 5 or more. Accordingly, for the *analysis case*, the number of x-marks should be 2 or less or of y-marks 5 or more to define an ease score designated by A, the navigational condition to be assessed should have ease score B, the number of x—and y-marks are between 3 and 4 and the lowest ease quality called C has to be assigned if the number of x-marks are 5 or more and 2 or less y-marks. But these numbers may change according to the ongoing discussion in WG 141.

5.5 Speed criteria – 2nd rating group

A scoring system as for the 1st rating group may be hard to define in case of the speed criteria. Therefore a direct assignation to possible ease categories was made in table 8 for three different criteria as the amount of vessel speed over ground, which scales especially the damage potential, the speed range, which describes the navigational room for manoeuvre and the amount of recreational traffic which hinders the freight vessels to ensure the safety of boat pilots.

A 1st attempt according to the discussion at the 8th meeting of WG 141 can be found in table 8, dealing with specific values for the speed over ground. The other two speed-related criteria are added in tables 10 and 11. The thresholds given for the maximum reachable ship speeds and the necessary vessel speeds to ensure a safe trip respectively, may help to quantify possible restrictions to ship speed according to the necessary or existing ease category. The table follows measurements concerning speed in nearly unrestricted channels as large rivers, speed limits in canals according to existing guidelines and local regulations, e.g. for very small and shallow canals and in Canal Grande in Venice (5 and 7 km/h) as well as typical vessel speeds approaching a lock.

designation of vessel speed	speed over ground	in order to achieve:	ease score
no restrictions	≥ 13 km/h	avoiding severe damage and danger of life and limb in case of accidents	A
adapted speed	ca. 9 – 10 km/h	reduced interaction forces in case of meetings	A, B
small canal speed	ca. 7 km/h	reduced wave heights, e.g. to avoid conflicts with pleasure boats	B
reduced speed	ca. 5 km/h	reduced bank forces	B, C
strongly reduced speed	ca. 3 km/h	no significant interaction forces	C
creep speed	< 2 km/h	no significant damage in case of accidents	C

Table 8: Assignation of ease of navigation categories to the vessel speed over ground

The assignation of ease scores to vessel speed is the same for the design and analysis case, because a high achievable ship speed in an existing situation speaks for a high ease score and the necessity for high ship speeds in design demands for a high ease category. But the ease scores for the 2nd criterion, the vessel speed range, may be different for the design and the analysis case. If there is for example only a narrow speed range possible in a design case, e.g. because the water depth is low, this small possible speed range demands for a higher ease category, e.g. for a wider navigational space, but a driving situation to be assessed in the analysis case with the same narrow speed range indicates a low ease quality. This holds also true for recreational boating, because traffic with many private boats demand for a higher ease category, but reduces the ease quality of freight vessels in the analysis case. Therefore, tables 10 and 11 distinguish the analysis and design case for the speed criteria as in table 7.

5.6 Traffic density criterion– 3rd rating group

One of the most important arguments to choose adequate standards is the level of traffic. It can be found e.g. in MARCOM WG 49 to define extra width in case of high traffic density. Analogous to the Dutch waterway standards, which says that e.g. the so called “narrow profile” (maybe ease level C) is

adequate for traffic below 5000 crafts per year, WG 141 assigned adequate ease categories to the number of commercial vessels (sum of both driving directions) per year in a cross section considered, see table 9. It assesses the ease for the design case only.

As shown for the speed range criteria, the assessment of the existing ease quality may be different, leading to a lower existing ease score in case of high traffic density. This will be accounted for in tables 10 and 11.

vessels per year, commercial navigation	selection of waterway profile	possible assignment of ease category in design case
> 30,000	further studies required (e.g. extra lanes to accommodate such high traffic)	A
15,000 – 30,000	normal profile for two-lane traffic	B
5,000 – 15,000	normal profile, narrow profile for short sections	B, C
< 5,000	narrow profile for two-lane traffic, single-lane profile in exceptional cases	C

Table 9: Assignment of ease of navigation categories for the design case to traffic density of commercial navigation

5.7 Combination of arguments for existing and required ease categories

As stated earlier, all criteria to define ease categories were collected in tables 10 and 11. Because the assignment to the criteria, e.g. coming from tables 6 – 9, is not unique in every case, we avoided to draw lines between the different rows with ease categories for all criteria. It should be pointed out that the assignment is still not balanced in WG 141 and that the designations to the importance of recreational boating are not assigned to specific values. The approach should show its worthiness if it should have been applied to different new designs and different existing fairways. This should be a work for the following meetings of WG 141.

ease category, score, quality	design case – minimum necessary or acceptable ease category						
	mixed criteria		criteria related to vessel speed			traffic	
	no. of x marks	no. of y marks	strived speed over ground (km/h)	designed possible speed range (km/h)	recreational traffic, especially muscle craft	no. of freight vessels per year	
A	≥ 5	≤ 2	> 15	≥ 14	≤ 2	high	> 30,000
B	3 - 4	3 - 4	9 - 10	7	3 - 5	average	15,000 – 30,000
C	≤ 2	≥ 5	5	3	≥ 6	low	5,000 – 15,000
			2				< 5,000

Table 10: Assignment of ease categories to criteria from tables 7 (mixed arguments), 8 (speed) and 9 (traffic density) for the design case

6. CONCLUSIONS AND FURTHER ACTIVITIES OF WG 141

The PIANC INCOM WG 141 on “Design Guidelines for Inland Waterways” has now been working on its tasks for 4 years. Our workshop on the occasion of the SMART Rivers Conference leads to revisions or first drafts of several essential chapters of our future report, like those to existing

guidelines, the three approaches in waterway design and the safety and ease of navigation considerations. We are therefore optimistic that a first draft of the guidelines may be worked out in 2014. Nevertheless, some topics are still under discussion, especially concerning the choice of adequate safety and ease of navigation categories, the reference of these categories to best practice examples or the application limits of ship handling simulators.

ease category, score, quality	analysis case – assessment of an navigational condition according to ease					
	mixed criteria		criteria related to vessel speed			density of commercial traffic
	no. of x marks	no. of y marks	drivable speed over ground (km/h)	usable speed range (km/h)	recreational traffic, especially muscle craft	
A	≤ 2	≥ 5	> 15 ≥ 14 9 - 10	≥ 6	low	low
B	3 - 4	3 - 4	7 5	3 - 5	average	average
C	≥ 5	≤ 2	3 2	≤ 2	high	high

Table 11: Assignment of ease categories to criteria from tables 7 (mixed arguments), 8 (speed) and 9 (traffic density) for the analysis case

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