Paper 34 - Workshop on Design Guidelines for Inland Waterways Introduction to WG 141 Approach and Findings

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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. In so far 12 meetings and three interim meetings on special questions, the group developed a three-step approach for designing an inland waterway. The design will be supported by a new approach to account for the safety and ease of navigation. The report provides also Guide Notes on the optimal use of ship handling simulators for waterway design purposes. This paper provides a brief introduction into the structure of the future report of WG 141 and some more detailed information on the last version of the safety and ease approach with special respect to usage of vessel simulation techniques.

0. PREFACE

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.

The working group performed so far 12 meetings, three interim meetings on special questions, a workshop within the framework of the Smart Rivers Conference in Maastricht two years ago and a contribution to the PIANC World Congress in San Francisco last year. An overview on the main activities in these events is given in Table 1. With reference to the publications of the Smart Rivers Conference (SRC shortly) in 2013 (Söhngen & Rettemeier, 2013a) and the contribution to the PIANC World Congress last year (Söhngen & Eloot, 2014), dealing with detailed information about the working group process up to meeting 8, only some brief information about the decisions and findings of the 10th up to the 12th meeting will be given in the following:

The main topic of the 9th meeting was the analysis of practice examples concerning fairway widths in rivers. One problem with existing data arose that it is not clear in all cases, whether the permitted traffic situation with the largest vessels will really happen, especially in curves. If this is not the case, the fairway width does not fit to the traffic situation assumed – but this is necessary if one wants to use practice data for design. If one e.g. assumes that the traffic really happens as permitted, e.g. meetings in narrow curves, but this assumption is wrong, one will end up with an undersized fairway. On the contrary, especially if one assumes one-lane traffic for the largest vessels, but in reality there will be meetings maybe with smaller vessels, the practice data lead to overdesigned fairways. A second problem is that in many cases it is not clear, whether the fairway, especially if it is bounded by buoys, includes safety distances to banks or not.

Besides these problems with the interpretation of practice data, the analyzed fairway widths show first that they generally fit to the design of canals concerning the influence of river curvature. Second, no significant influence of the flow velocity could be derived from this practice data. This does not mean that there is no influence existing, but practice shows that the vessels may have the chance to overcome this design aspect. But the data show clearly that the fairway in rivers should be at least 1 or 2 ship's beams wider than the one for canals. These differences can be assigned to the existing ease quality of the navigation on the rivers considered. WG 141 decided for this reason to support these findings by additional practice examples and to compare them with those from existing guidelines, especially from USA, because they include curvature and flow velocity influences.

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	Comm"erc"ial 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 (SHS)	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 (s&e) and 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
9	2014, Bonn	Practice examples fairway width in rivers according to PIANC World Congress San Francisco 2014 (SFC)	Analysing additional practice data and comparison with guidelines, especially those from US with flow influence
10	2014, Lille	Test of SFC safety and ease approach in the light of examples	Demonstration of WG 141 recommen-dation by application to examples
11	2015, Brussels	Collection of contributions to the future report and distribution of tasks concerning open points	Agreement to perform a new workshop at SRC in Buenos Aires, simplifying s&e approach
12	2015, Duisburg	Discussion of all the existing contributions to the report	Agreement concerning process recommendation for SHS usage

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

The 10th meeting in Lille brought a breakthrough concerning the refined safety and ease of navigation ("s&e" shortly) approach (Söhngen & Eloot, 2014), which distinguishes between the *analysis* and the *design* case. It was applied by the members to different exampled and demonstrated its general applicability. We then discussed how to quantify ease quality in case of using ship handling simulators ("SHS" shortly in the following) or field data. After SHS developers and users in the group, this can be handled by comparing numerical numbers quantifying the "deviation", e.g. from an aimed course and those indicating the "control" of the vessel, e.g. the necessary rudder angles, between analysis or existing situation and design case. This "comparative thinking" reduces unavoidable inaccuracies of the design methods used and will be explained in more detail in Paragraph 5 of the present paper.

The group discussed the first drafts of different Chapters during our 11th meeting in Brussels 2015 and agreed about the magnitude of each Chapter and the general layout of the report. The WG then distributed tasks to fill up lacking information in the report and discussed the refined s&e approach according to the paper for San Francisco again and agreed that the different criteria should be collected to one s&e index only. This index will be assigned to ease categories, which in turn allows to choose adequate waterway dimensions by using e.g. the

Concept Design Method, see Paragraph 6 in this paper.

The focus of the 12th meeting in Duisburg at DST (Development Centre for Ship Technology and Transport Systems) was on the approach to account for s&e demands in using SHSs. The group agreed to work out recommendations concerning the optimal usage of SHSs with special respect to this aspect. It is basing on a quantitative comprehensive index for the difficulty or easiness of the driving situation, and the approach will consequently use the principle of a comparative variant analysis. This will be worked out a little bit more in this paper, see Paragraph 5. The index uses simulation results, e.g. the number of steering actions per minute or the exploitation of possible rudder angles during a design-relevant manoeuvre.

Summarizing the review of the working group progress, the group finished the review of existing guidelines and analyzed several practice examples. Basing on these information and facing the problem that not all design problems can be handled using these data, it worked out a three-step approach for designing an inland waterway, starting with the Concept Design (Söhngen & Rettemeier, 2013a und 2013b, Rettemeier & Söhngen, 2015), taking knowledge especially from relevant international guidelines (Rettemeier, 2013), over the Practice Approach (Söhngen & Eloot, 2014, Rettemeier & Söhngen, 2015), using experiences from existing waterway dimensions (Koedijk, 2013), up to the Detailed Design, which is basing generally on simulation techniques for design (Eloot, 2013 and 2015, Iribarren 2015). Special respect is made to the consideration of safety and ease of navigation (s&e shortly in the following) in the design process (Deplaix & Söhngen, 2013, Söhngen & Eloot, 2015, Deplaix 2015), both in using simplified methods as Concept Design as well as using ship handling simulators..

A first draft of the future guidelines is available since July 2015. It is planned to start the coordination with PIANC headquarters in the beginning of 2016. This document gives a short insight into the structure of the report, using the same numbering of the paragraphs as the chapters in the report. The focus is on Chapter 1 (introduction) concerning the contribution of the report to the general process in waterway design and Chapter 5, dealing with the way how s&e demands will be accounted for, both in using the Concept Design as well as Detailed Design.

1. INTRODUCTION

The 1st Chapter in the future report looks first on the motives to install a new WG. One of these is the lack of internationally balanced standards for inland waterway design, especially for new, bigger and stronger powered vessels. Another motivation comes from the changed legal requirements concerning the ecologic footprint of planned measures. This demands for specifying the minimum necessary 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.

The differences to MARCOM 49 approach for sea-going vessels will be discussed next, ending with the statement that inland vessels are very much more powered, related to their mass, and better steerable than sea-going vessels and that the damage by an accident of inland vessels is also minor to sea-going vessels as stated earlier. So, the safety and ease standard in inland waterway design can be chosen lower and therefore the necessary waterway dimensions will be smaller compared to sea-going vessels. Also the design approach may be different, especially concerning the consideration of safety and ease of navigation.

From this, a general procedure for performing a waterway design and how to use the report will be presented (Söhngen 2015, Eloot, 2015, Iribarren 2015), stating e.g. that inland waterway design needs generally a looped approach. This means, that e.g. the boundary conditions for design as vessel type, draught, water stage, visibility conditions, wind speed and especially the nautical situations to be considered, even the methods used for design, have to be questioned and if necessary adapted, e.g. if there are unexpected differences between designed values to existing experiences or if the impact of the planned measures are much bigger than expected.

But this concerns to the design process itself, not to the entire planning process. This means, in particular, that the waterway improvement measures proposed are not put into question in the report of WG 141. 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 will be discussed in the recommendations, as e.g. the necessity of two-way traffic or the choice of appropriate safety and ease of navigation standards.

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*.

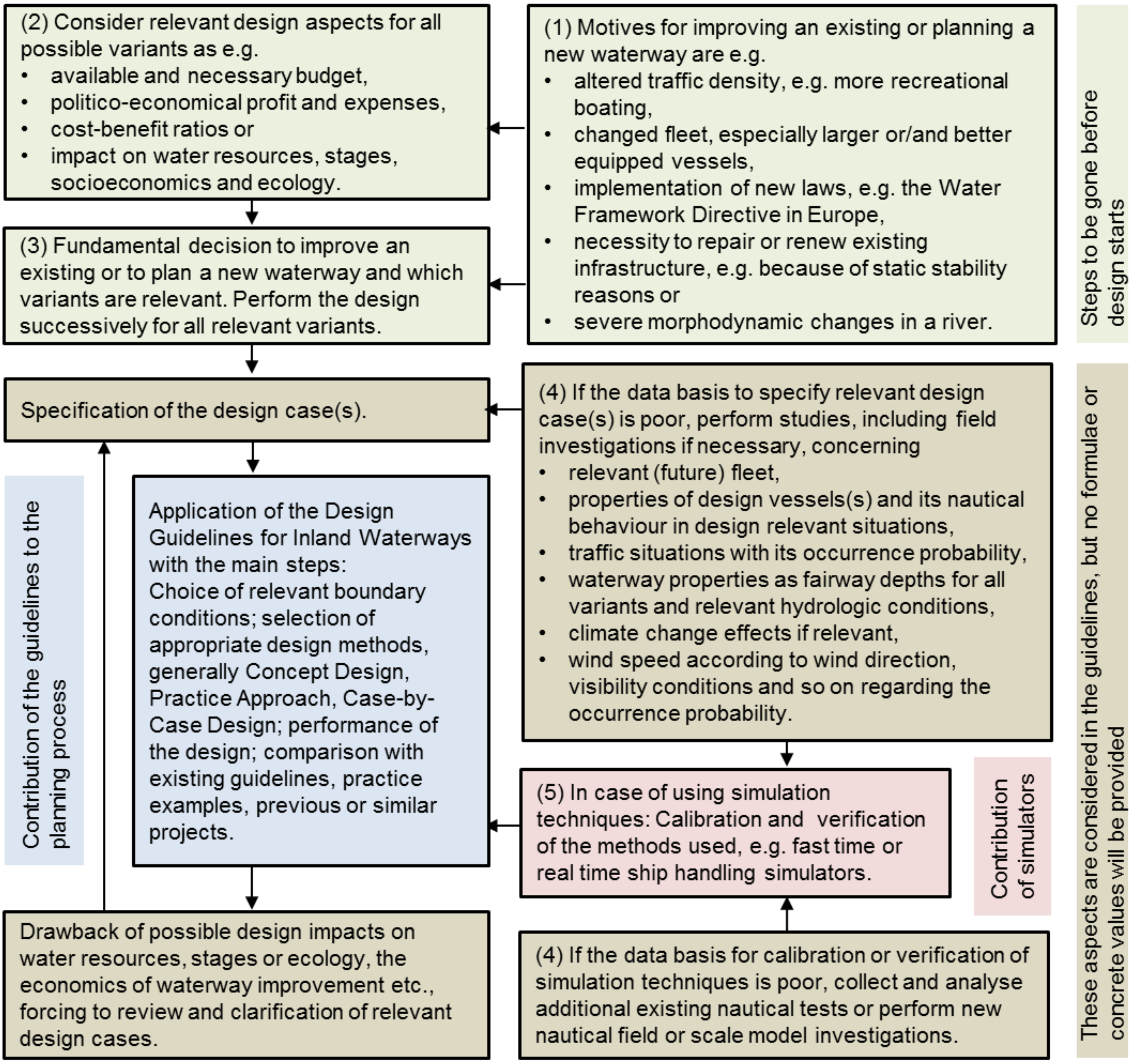

Figure 1: Contribution of the WG 141 report to the planning process on an inland waterway

The reason of this restrictive approach is not that the group members wouldn't be able or willing to give more comprehensive answers, but there will probably be no chance to get extended recommendations balanced with PIANC members and even an agreement within the working group maybe complicated, besides the fact, that extended recommendations would burst the usual framework of an PIANC guideline. 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 only.

This contribution of WG 141 report to the general planning process of an inland waterway is illustrated in Figure 1. The blue colored boxes indicate its *direct* contribution, meaning that e.g. concrete values for waterway dimensions will be given. The activities collected in the grey boxes are also part of the report, but in the sense of process recommendations or hints on what has to be considered and which data or supplementary information are needed. The light green colored boxes in Figure 1 concern to all the activities that have to be carried out in advance or after using the WG 141 report.

2. DISCUSSION OF EXISTING GUIDELINES

This chapter of the future report gives a brief summary on all the guidelines considered by WG 141. Because the outcome of these guidelines forms the backbone of the Concept Design Method, more detailed information will be provided additionally in an appendix to the report.

One example of the recommended waterway dimensions will be given in the following. It concerns the lock harbor lengths, see Table 1. One can see the party huge differences in the values given, which forced the group to define different ease categories for design and to assign these categories to the recommended values of WG 141.

This is because especially the properties of design vessels, but also the boundary conditions may be different from case to case and therefore from country to country. If e.g. the design vessels are poorly powered and if the strength of currents is high, which is a driving situation with a low ease category, the helmsmen will be forced to steer the vessel full ahead into the upper harbor to counteract the cross flow and to stop not until the vessel is fully inside the sheltered water of the upper harbor. In this case the approach length should be at least twice the vessel length L or more. One L is to ensure that the vessel is geometrically inside the harbor before beginning the stopping manoeuvre, and another L is a good estimate for stopping in still water. By contrast, if the flow velocity is moderate and the vessels are strongly powered, the vessels may be able to stop upstream of the separating dam and sail with bow thruster assistance through the cross current field. In this case, the lock approach length maybe 1 L only. These aspects are accounted for by the different national guidelines.

Since a study on the approach channel would only be a small fracture of the overall cost of a lock, the working group decided to recommend case by case studies for lock approaches in rivers in general and to use the values given in national guidelines, Concept Design or practice data for preliminary design purposes only. Nevertheless, this design step is necessary in every case, because both the bathymetry and the flow field in the vicinity of a lock approach will be influenced by the waterway dimensions to be designed, here especially the lock approach width. So, one has to know the dimensions *before* making simulations, even so if the necessary dimensions are the aim of the study! If the results from simulations are not satisfactory, the preliminary design has to be adjusted, and possibly the flow model too, before new simulations can be run. This is the reason why Concept Design is always an important step also in case of performing a detailed study!

Concerning lock approaches, Chapter 2 of the future guidelines proposes at least 2 times the ship beam (3 - 4 times ship beam for double lock) for the entry width and at least one times the ship length (without mooring area) for the lock approach length as a starting point for a detailed design in case of modern vessels. The lock approach depth should be at least 1.4 times the draught to ensure that the crosswise force on the underwater body of the vessel while drifting e.g. through cross currents will stay controllable. Another criterion concerning necessary water depth is that modern bow thrusters, sucking water from below, can work effectively. For this reason, the water depth in the lock approach area and the harbor should be at least 0.5 m plus squat (say 0.2 m) more than the maximum draught.

Table 1: Lock approach widths B_{LA} and lengths L_{LA} in different Guidelines as factors of ship beam B and Length L (*from top of jetty to lock entry) for single (s) or double locks (d)

Guideline	B_{LA}/B	L_{LA}/L
China	3.5 - 4.5 (s)	3.5 - 4.0
	7.0 (d)	3.0 - 3.5*
Dutch	2.2 (s)	1.0 - 1.2
French	2.9 (s)	0.5
Germany	2.5 (s)	2.2

3 DIMENSIONS OF EXISTING WATERWAYS

The next chapter collects and discusses data from waterways in use. The group called the examples "best practice" first, but because several practice examples obviously did not fit with the requirements of safety and ease of navigation, the examples were called "practice-data" only.

One of the reasons for this is that partly very much larger vessels got the permission to sail in existing waterways, which were designed for smaller vessels only. Navigational practice show that these extended permissions are responsible in many cases due to the good navigational properties of modern vessels, meaning that the safety of navigation is just ensured, but at the price of a reduced ease of navigation!

Nevertheless, the provision of relevant practice data and its comparison with corresponding values from existing guidelines and Concept Design, helps to find out the possible range of uncertainty of the waterway dimension to be designed – and thus, to decide, whether a detailed study is necessary or not. But also if there are no data available from guidelines or Concept Design, as it is the case for rivers with strong currents, the practice data can be a second pillar in comparison to simulation results.

Because detailed information were available concerning the fairway dimensions in rivers, these data could be provided to the reader of the report in a more meaningful graphical form, basing on the recommendations for canals concerning the minimum navigational width in straight reaches and corresponding additional widths in curves. This shows the following Figure 2 for one-lane traffic in rivers (for two-lane see Rettemeier & Söhngen, 2015), which is a refined and extended version of the one in (Söhngen & Eloot, 2015). For applying it to a concrete situation, one has to know the curvature radius R and the overall dimensions of the vessels only.

Considering the spread of data, which may be interpreted according to different ease qualities as indicated in the graph by colors from green (ease quality A - nearly unrestricted drive), which correspond to the largest values of the fairway width, over yellow (B - moderate to strongly restricted drive) to red (quality C - strongly restricted drive), which correspond to the smallest fairway widths, the data show that the fairways in use are not significantly wider in case of strong currents as in free flowing rivers than in dammed rivers. Also no significant influence can be seen from the data concerning the way how the the fairways are bordered, e.g. by buoys, groynes, parallel dykes or bank slopes. So, it is not possible to decide from the data and Figure 2, whether it is necessary to add safety distances to structures or not. To stay on the safe side in design, it should be assumed that the fairways are bounded by buoys, so that extra allowanced e.g. to counteract cross currents at groynes should be added to the fairway widths from Figure 2.

As mentioned earlier, some other assumptions were necessary e.g. concerning the corresponding driving situation to draw Figure 2, because the officially permitted traffic situations as meetings may nevertheless be avoided in practice in narrow curves for the largest permitted vessels. Therefore only the largest permitted vessels were chosen for drawing the graph and in case if there were doubts about the traffic situation, one decided to take the data for one-lane traffic instead of two-way.

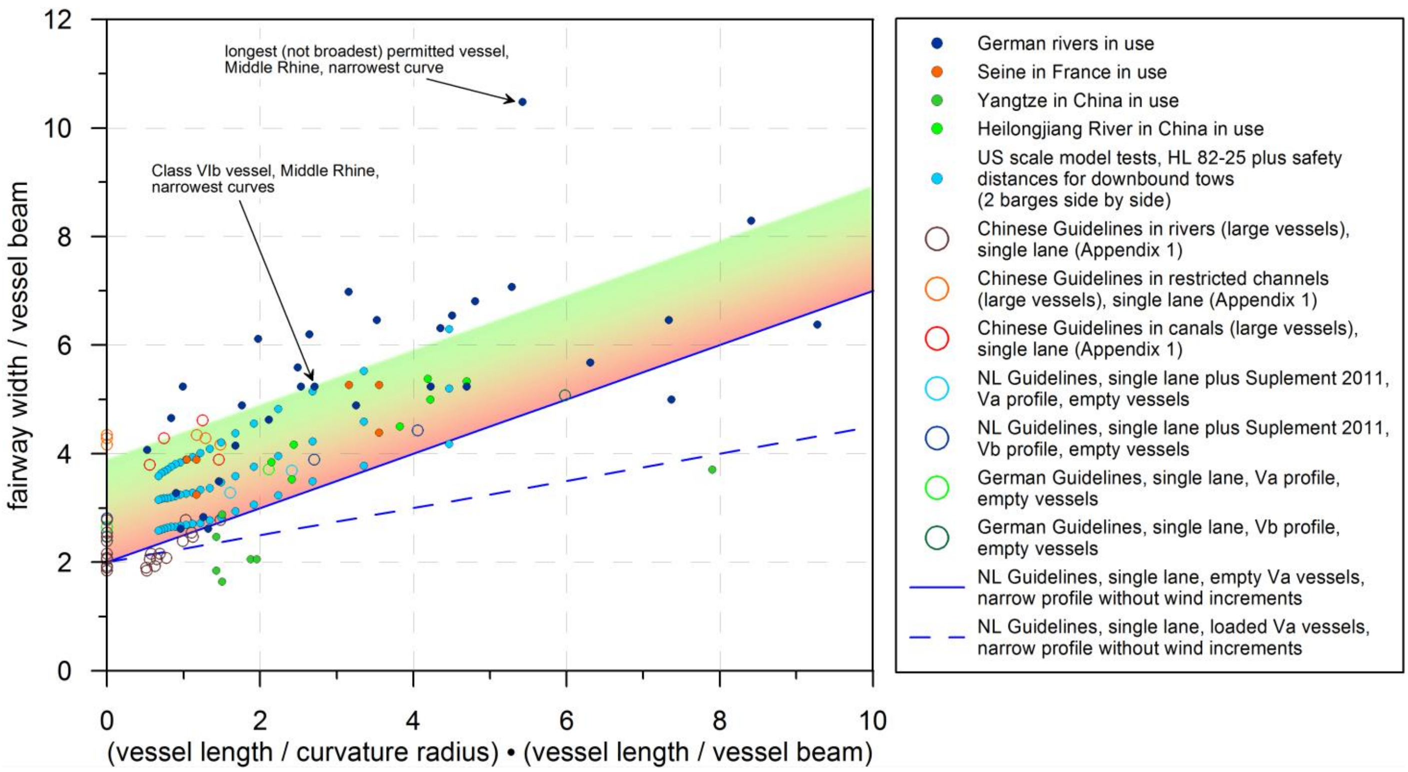

Figure 2: Existing fairway widths (in draught depths, related to vessel breadth) in rivers and from guidelines for one-lane traffic, interpreted as to be limited by buoys (s&e interpretation: A, B, C)

Because not only practice data were included in Figure 2, but also those from existing guidelines, one can see that the increase of fairway widths by the parameter L^2/R fits well with the corresponding extra width in curves for empty vessels (0.5 L^2/R). With reference to e.g. (Söhngen et al., 2013b), this corresponds to a position of the pivot point to be at the vessels bow. Because this position can be far ahead of the vessels bow in case of conventional vessels without strong bow thrusters or passive rudders and strong longitudinal currents in a downstream drive (Fischer et al. 2014), Figure 2 should be used for design purposes for modern vessels and moderate relations of R/L only. Nevertheless, the graph gives a good idea on necessary fairway widths for preliminary design purposes or to validate results from a detailed study. It shows again the a.m. huge differences in accepted safety and ease standards in practice and the necessity to perform case by case studies using e.g. simulation techniques or field investigations for design, if critical boundary conditions have to be accounted for as strong wind, currents, narrow and poorly powered vessels.

It should be mentioned at this point, taking the blue colored data from US guidelines in Figure 2 that, the necessary fairway widths are strongly dependent on the driving style. The big US tows or those on the River Parana e.g. sail if necessary in narrow curves very slowly downwards while penetrating relative to the surrounding water body upstream! This corresponds from the viewpoint of driving dynamics to an upstream drive, where the pivot point is far behind the vessels bow, resulting in reduced necessary extra widths in curves. Nevertheless, the data from US recommendations fit with the other data used for drawing Figure 2, but may come up with smaller fairway widths in narrow curves, if one accepts the very low ease standard assigned with this special driving style.

4 TECHNICAL INFORMATION

Chapter 4 starts with the classification of waterways and specifies the properties of correspondent design vessels (Koedijk, 2015). These are not only the overall dimensions, but also the installed power and the type and effectiveness of rudders and additional thrusters. This is important, because the necessary waterway dimensions are strongly depending on the navigational properties of the design vessels.

Next, design-relevant properties of waterway types will be discussed (Deplaix, 2015). It will be shown as a special aspect in narrow cross sections as canals (Pompee 2015) that, the possible ship speed is physically restricted by the critical speed (see also VBW 2013, now available in English, where the influence of driving dynamics of inland vessels on waterway infrastructure will be discussed in more detail). The latter can make problems in using standard ship handling simulators, which do not account for this effect properly, meaning that e.g. the chosen vessel speed during a simulation run is too high. This in turn may lead to a faulty evaluation of e.g. ship-ship or ship-bank-interaction forces and so, to wrong decisions about the necessary navigational space.

Another problem discussed in Chapter 4 is the influence of very high T/d-ratios on the crosswise forces while drifting. If T/d reaches 1, what can happen e.g. in natural rivers at gravel banks, the crosswise forces almost explode compared to usual maximum T/d of about 0.7 - 0.8. This “airfoil-effect” in turn can make the vessel nearly uncontrollable, but common simulation software delivers only a rough approximation of this design-relevant vessel behavior for very high T/d.

Because there are always some physical effects that cannot be modelled optimally at the present stage of knowledge, one has to know on how these modelling inaccuracies can be accounted for properly, e.g. by using comparative considerations, which will be recommended generally in using simulation techniques. This principle will be discussed next in Chapter 4 of the future report from the viewpoint of the driving dynamics of inland vessels. The chapter ends with recommendations on necessary data needed, depending on design vessel properties, waterway types and relevant driving effects to be considered in design.

5 CONSIDERATION OF SAFETY AND EASE

The necessity to consider s&e aspects for design purposes and the way how to account it for in using the Concept Design method were discussed detailed in several previous papers from authors of WG 141 (e.g. Deplaix & Söhngen, 2013 and Söhngen & Eloot, 2014). This approach, which helps to assess the ease quality of a driving situation under consideration, e.g. the existing one (in the following called “present nautical condition” or “png” shortly) or a well-known driving situation with appropriate ease quality (called “ease reference case” or “erc”), which shall be used as a reference case for comparing it to the ease quality of the “design case” (shortly “dc”), will be called “simplified method”.

It is mostly basing on checking the validity of arguments, together with some relevant waterway data, but not on concrete values defining the difficulty of the driving situation as the number of necessary hard rudder actions per unit time, because these data generally are not available in a preliminary design state. The simplified method was improved since (Söhngen & Eloot, 2014) by using a comprehensive ease score, matching several criteria altogether, in order to simplify comparisons.

The new approach will be applied to an example, concerning the tricky drive through a narrow bridge in the German Neckar River (Söhngen et al. 2015) with presently permitted shorter and in future longer vessels, to find out the appropriate ease quality for design and so, to be able to apply the Concept Design Method and the practice approach according to Figure 2, which are depending on the chosen ease quality. Both methods will be applied apart from that by using consequently the principle of comparative variant analyses, meaning e.g. that, not *absolute* values of the necessary fairway width will be used, but the *differences* between design and reference case.

This principle of performing a comparative analysis is also the basis of the "detailed s&e approach". It uses analogously a comprehensive ease score to the one of the simplified approach, but it takes concrete results from measurements or simulations as the exploitation of existing resources as the navigational space or the necessary percentage of installed power of a bow thruster (Iribarren, 2015; Eloot et al. 2013, Eloot 2015). This comprehensive ease score can then be used for comparing different variants with each other or with the chosen ease reference case.

Figure 3 illustrates this procedure, which comprises both the simplified (blue colored boxes in Figure 3) and detailed s&e approach (green colored). Because it is almost self-explanatory, it will not be commented further in the following.

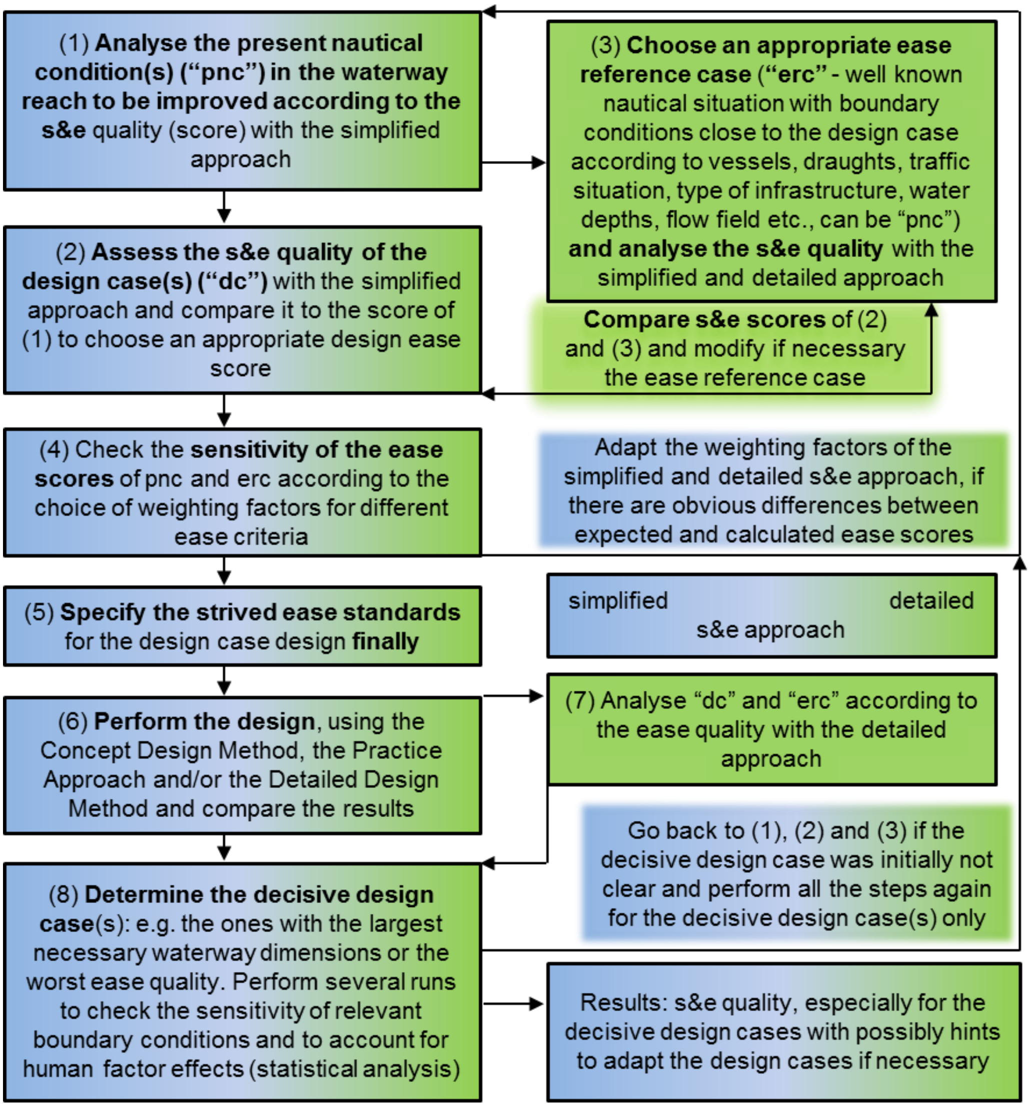

Figure 3: General approach to consider the safety and ease of navigation ("s&e") quality for design, both using the simplified and detailed approach in case of a waterway reach to be improved

It should be noted here that the simplified approach to assess the navigational quality in an inland waterway, was under discussion nearly in all WG 141 meetings. One reason is that all the members had, and also the readers or appliers of the report may have, their own understanding on how the term "safety and ease of navigation", which is used in many waterway related laws, could be interpreted correctly and used properly for design purposes. Another reason is that many different criteria may be relevant – and that they change from case to case, too. Hence, the proposed approach may not be the best possible one, especially not the best for the specific design case considered. But WG 141 proposes one at all. This is the most important statement. Furthermore, the simplified approach will help the reader of the report to sharpen his view on the most important aspects of waterway design related to s&e.

It should be noted further that the simplified approach focusses on the ease of navigation only, not on the *safety*, because the general statement of WG 141 members is that the safety of navigation should be ensured in each case in design. This is why only those waterway dimensions will be proposed herein that fulfil this important criterion.

The detailed s&e approach is outlined in more detail in the following Chapter, including some general recommendations concerning the optimal usage of simulation techniques for waterway design purposes.

6 RECOMMENDED DESIGN STEPS

Especially for tricky navigational conditions, WG 141 recommends generally the performance of three design steps (Rettemeier & Söhngen 2015, Söhngen & Eloot 2014):

- Concept Design,
- Practice Approach and
- Detailed Design.

Using all the three design steps may be not necessary, if the Concept Design Method is satisfactorily applicable, meaning that national or international guidelines, which are described in detail in Chapter 2 and Appendix 1 and the special recommendations in Chapter 7, match properly with the design problem to be solved, especially with the local boundary conditions and the aimed ease standard. But even in these cases, a comparison of the Concept Design results with practice examples will be recommended to evaluate the results.

Especially, if there are large differences between the values from design and Practice Approach, one should review the boundary conditions for design. In complicated design cases or if there are large differences between the local boundary conditions to be considered and those in existing guidelines or experience, one should perform all the three steps recommended as already stated earlier..

Because the Concept Design is generally the same as applying guidelines, which was discussed in paragraph 2 of this paper, and because an important practice example was shown in paragraph 4, only the recommended approach to perform a detailed study will be outlined in the following. The focus is on ship handling simulators, because these simulation techniques are more and more in use nowadays, not for training only, but also for design purposes.

More information on the necessity to use simulation techniques for design purposes, the optimal use of these methods from the technical point of view and limits of application can be found e.g. in (Söhngen et al. 2013a & 2014) or (Eloot et al. 2015). So, the focus is here on s&e demands in using simulators. This especially, why this aspect in waterway design will often be underestimated or neglected, because there is no general accepted procedure published for it and because even the best full bridge simulator is still not reality. This holds also and especially true for human effects and so, safety and ease demands.

But also the physics of a ship's behavior in shallow water is only a somewhat rough approximation of the reality. This is e.g. the case, if interaction forces between vessel and waterway as in very restricted canals or during entering a lock chamber dominate the design or if a strong flow field is important. The latter is generally not exactly represented in the simulator, e.g. because of budget restrictions or because it may change significantly by the moving vessel as while sailing in the vicinity of groynes.

These inaccuracies of the simulation techniques can be reduced as outlined before and explained in detail in (Söhngen & Eloot, 2014) by using the principle of comparative analyses. It will be demonstrated by an example in (Söhngen et al., 2015).

The corresponding procedure is shown in Figure 4, which is still under discussion in WG 141 concerning necessary details to be dealt with, but not the general approach at all. It may sound somewhat academically to consider and compare results of three different variants, which were explained in Chapter 5: "pnc", "erc" and "dc", besides another variant, the so-called "verification reference case" "vrc", which is used to evaluate the simulator for design-relevant boundary conditions, but in most applications all the three reference cases can be the same, e.g. the existing situation, if the corresponding ease quality of the largest permitted vessels can be accepted for design too, if data from e.g. field tests are available to compare them with simulation results and if the data are close to the driving situations considered for design. Because Figure 4 is mostly self-explaining and with reference to the future report, it will not be commented further in this paper. But because the approach of Figure 4 can be used for fast time simulations too, some remarks concerning the consideration of human effects in fast time simulations shall be added:

It is obvious that the human factor can only be accounted for *directly*, if field tests and real time ship handling simulators will be used. Steering by an imperfect autopilot as shown e.g. from (Ji Lan et al. 2010) can extent fast time simulation to human factor effects. But without these extensions, fast time simulations need corrections to account for human factor effects, e.g. by empirical additions to relevant waterway dimensions.

This may be acceptable if the influence of the helmsman is limited or small compared to the deterministic parts of waterway design as extra widths due to cross currents and thus can satisfactorily be assesses by adequate formulae or numbers provided in many guidelines (extra swept area width due to a sinusoidal drive). But one needs a direct consideration of human effects especially in critical conditions. These are depending on:

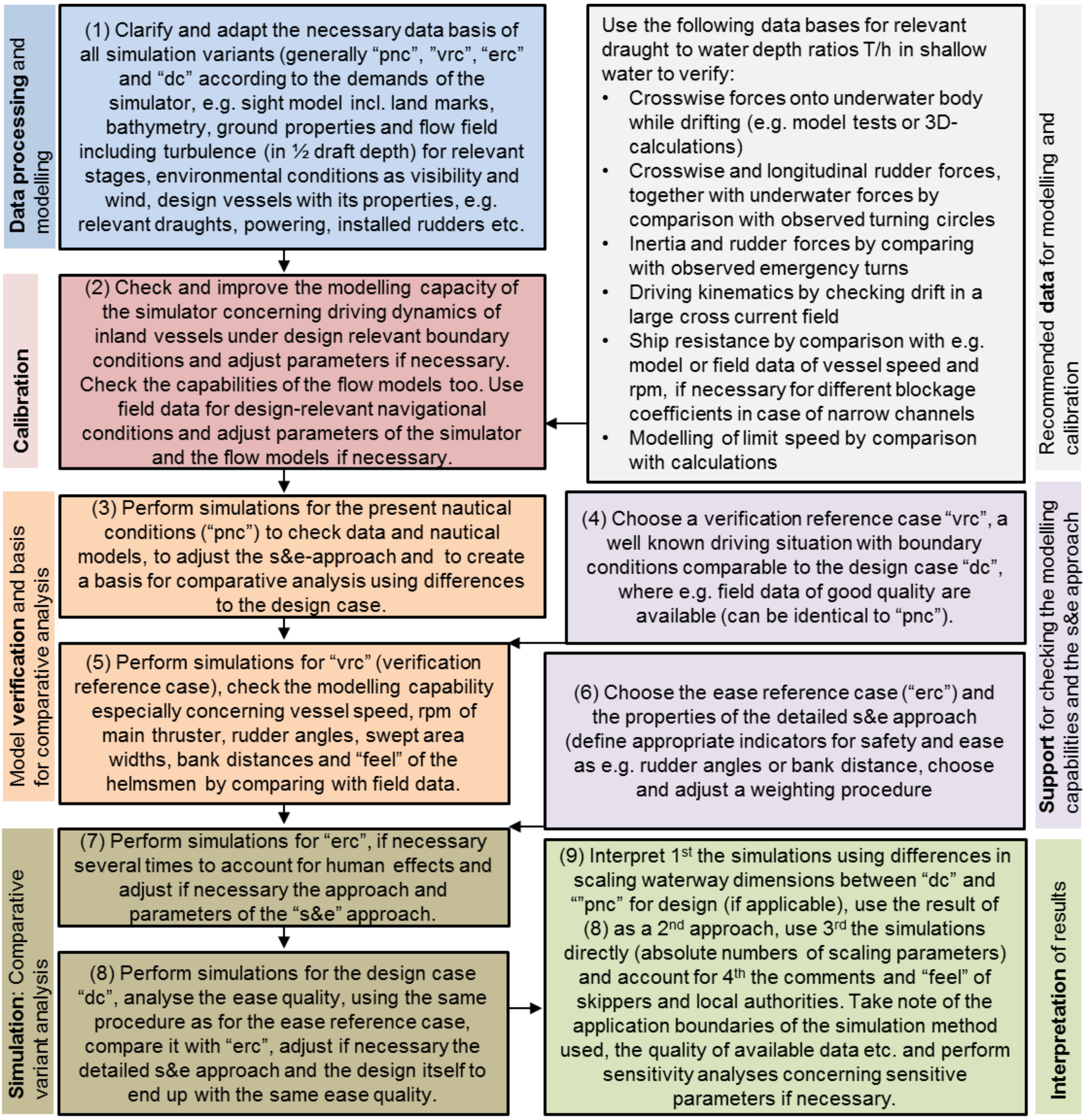

Figure 4: General Recommendations for using vessel simulation techniques as full bridge ship handling simulators (together with Figure 3) in case of a waterway to be improved.

• The limited accuracy of orientation and information, caused by usual nautical instruments used as ECDIS charts, radar, AIS and clearly the visual information concerning vessels course and speed, its position in the waterway with distances to relevant fairway boundaries as buoys, accounting for a possibly reduced sight in case of foggy weather or containers blocking the foresight, leading to inexact up to faulty decisions and steering actions,

• The reaction time, depending e.g. on the number and the quality of available information, the number of things to do simultaneously, the diversion and attention, stress, tiredness and experience of the helmsman, the time lag between command and vessel reaction, depending on the quality of steering devices and the inertia of the vessel, which changes due to added mass, e.g. in shallower water and

• The precision of steering the vessel, depending on the number of levers that will be controlled using the same hand, the familiarity of the helmsman with the ship, his skills, local knowledge and clearly his experience.

These few aspects show that the human factor is strongly related to the vessels properties and its behavior in shallow water. Therefore proper human factor modelling demands to a great extent not only to perform several runs for statistical analyses as mentioned in step (7) in Figure 4 and a proper visualization of the vessel and the waterway, especially concerning sight relations to landmarks, which is essential for proper orientation and thus the possible exploitation of the waterway, but also a proper modelling of the steering aids and clearly the driving dynamics of the vessel, especially related to its inertia in shallow water.

So, the operator of a simulator should demand his client for sufficient means to account for the a.m. aspects and the commissioner of a nautical study shall know that he has to deliver adequate data, not only below, but also above the water table for proper orientation, to mention just some of the a.m. aspects again.

7 SPECIAL RECOMMENDATIONS

All the information e.g. from existing guidelines and practice examples will be collected in Chapter 7 of the future report for each waterway dimension separately, namely:

- width and depths of canals,
- fairway widths in rivers,
- construction of junctions and turning basins,
- width and headroom of bridge openings,
- lengths, widths and depths of lock approaches and
- length and layback of berthing places.

All subchapters of paragraph 7 contain a definition and clarification of the relevant dimensions first, e.g. the width of a canal in draught depth, then information on scaling parameters will be given as the ship beam in case of fairway widths in straight sections, check lists will be provided next on which data are needed for design as e.g. the number of vessels per year for ranking the necessary s&e quality, then the Concept Design will be applied to standard cases, e.g. straight waterway sections, extensions concerning e.g. extra widths in curves will be given next, then practice data provided and finally, additional information will be given, which aspects are relevant and how existing inaccuracies can be overcome in using simulation techniques. Because Chapter 7 is still under work, no further information will be given here.

8 CONCLUSIONS

Basing on the feedback from the audience of the two workshops at Smart Rivers Conferences in Maastricht and Buenos Aires and the balancing process inside the PIANC community before publishing the report will end with remarks, especially concerning present limitations of applicability of the report and corresponding open questions, which need further investigations. It shall be noted here that several design aspects had to be neglected in the present state of the report and maybe also in the final version, as e.g. the influence of navigation aids as buoys or modern track keeping systems on waterway design. Because it can be assumed that especially autopilots will revolutionize the navigation in future and may lead to narrower standards than valid today, it may be necessary to revise the future report of WG 141 within a few years.

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