Use of PIANC & IAPH method to determine the suitable dimensions of the first class water ways in Egypt

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The traffic density in Upper Egypt has grown heavily in the past years due to the numerous Nile Floating Hotels navigating that area, particularly between Luxor and Aswan, and may occasionally extend their route to Cairo. It can even be predicted that the traffic density will increase in the next years, hopefully, with the beginning of production from Toshka project and the requirement of an efficient means of transportation to deliver the products to the consumers and main ports in different parts of Egypt. Furthermore, in the northern part of Egypt, an increased attention is paid towards the implementation of inland water transportation to the transportation of cargo, particularly containers, from Alexandria and Damietta to Cairo. In this paper, a method for the determination of the relation between the main dimensions and characteristics of inland water units and those of the canal is presented.

شهدت حركة المرور في مصرِ العليا نموا مضطردا في السنوات القليلة الماضيةِ نظرا لوجود العديد من الفنادقَ النيلية العائمة التي تَجُولُ تلك المنطقة و خصوصاً بين الأُقصرِ وأسوان، والتي قَدْ تُمدّدُ طريقَها من حينٍ لآخر إلى القاهرة. ويُمْكِنُنا أَنْ نتوَقّع زيادة اخري في الكثافة المرورية النهريةُ في السَنَوات التالية، على أمل، ببِداية الإنتاج مِنْ مشْروع توشكا ِ وما يستلزمه ذلك من ضرورة توافر وسيلة نقل كفوءةِ لتَسليم المُنتَجاتِ إلى المستهلكين والموانئِ الرئيسيةِ في الأَجزاءِ المختلفةِ بمصر. علاوة على ذلك، في الجزءِ الشماليِ لمصر هناك اهتمام متزايد نحو تطبيقِ واستخدام وسائل النقلِ بالمياه الداخليةِ في شحنِ ونقل البضائع وخصوصاً الحاوياتِ، مِنْ الأسكندرية ودمياط إلى القاهرة. في هذا البحث نتناول طريقة لتصميمِ وتحديد العلاقةِ بينَ الأبعادِ الرئيسيةِ وخصائصِ وحداتِ الملاحة الداخليةِ مع ابعاد وخصائص القنوات والممرات المائية

Keywords: Inland waterways, Shallow and restricted waters, Maneuvering in restricted waterways, Relation between units and canal dimensions

1. Introduction

Since an increasing concern is directed towards the wide implementation of inland water transportation in Egypt, it is of prime importance to calculate the suitable dimensions of the navigational routes depending on the existing Egyptian fleet and the current conditions of the canals.

The dimensions of the navigable canals mainly depend on the overall dimensions and characteristics of units navigating the canal under consideration. In addition, the characteristics of the canal (current, wind, type of bottom …etc), the density of the traffic, speed on this specific canal, and the cargo hazard level are detrimental factors for the design of the navigational canal.

The inland water ways may be divided into:

1. Shallow water which is limited in the vertical direction (limited water depth).
2. Restricted water which is limited in the horizontal direction (limited water width).
3. Confined water which is limited in both vertical and horizontal directions.

Shallow water can be defined on the basis of water depth-draft ratio (h/T). In general shallow water effects become pronounced when $h/T \leq 3.0$[1].

The different behaviour of ships in shallow waters has been experienced and observed by a number of authors [2]. The flow distribution around a ship in shallow water becomes more two-dimensional and pressure distribution around the ship changes considerably, as compared to deep water. The pressure drop due to accelerated flow at bottom causes a ship to “squat.” Since the amount of the squat is proportional to the square of speed, the speed of a vessel traveling in a canal will be limited by this factor. The maneuverability of ships becomes poorer with the decrease of the water depth, and on the contrary, the course keeping quality is improved [3]. In shallow water, turning circle diameters increase by as much as 75% at h/T = 1.2. With h/T = 1.5, the changes in the turning circle diameter from deep to shallow water turning were much less [4, 5].

In restricted waters, a ship's behaviour is affected by the presence of the lateral limits of the navigation area, such as banks and quay walls. These restrictions would influence the hydrodynamic forces and moments acting on the ship's hull (bank effects) [6]. The bank effects depend on the ship-bank distance, speed, depth-draft ratio and bank geometry. When a ship is advancing parallel to, but to one side of a channel centerline, there occurs an asymmetric pressure field around the ship due to asymmetry of the flow field, consequently the ship will be acted upon by lateral forces and yawing moments. Another important problem is the interaction between two ships as they meet or pass each other in a narrow canal. In this case, they are affected by very complex forces and moments, which change their intensity and direction as the relative position of two ships changes.

It should be clearly pointed out that the navigational canal together with the fleet and the locks represent the main elements of inland water transportation, therefore the maximum dimensions of the locks, and the best way to utilize them are the main factors in the determination of the relation between units and locks dimensions. The lock dimensions should be multiples of that of the units to insure the maximum capacity of the waterway and the minimized water loss through the locks. Keeping all of the above-mentioned points in mind the preliminary overall dimensions of inland water units can be setup.

The report of the joint working group of the Permanent International Association of Navigational Congresses (PIANC), and the International Association of Ports and Harbours (IAPH) (June 97) [7] represents a good approach for the calculation of the navigable canal dimensions. The report is dedicated for the design of approach channels and the determination of a channel dimensions according to the navigating units' dimensions and speed, such that the effects of restrictions on the maneuverability of ships navigating the specified channel is kept to an acceptable minimum to insure safe navigation.

In the design of the navigational canal, one must distinguish between the navigation in straight sections, in bends and in S shaped bends.

2. Navigation in straight sections

The bottom width (*W*) of the waterway is given for two-way channel by [7]:

$$W = 2W_{BM} + 2\sum_{i=1}^{n} W_i + W_{Br} + W_{Bg} + \sum W_P$$

where the different terms for channel width are shown in figs. 1 and 2. The basic maneuvering width *WBM*, as a multiple of the beam B of the unit to be designed, is given in table 1. *WBr* and *WBg* are the bank clearances on the 'red' and 'green' sides of the channel, $\sum W_P$ is passing distance (comprising the sum of a separation distance based on ship speed and an additional distance based on traffic density) and the *Wi* are additional widths given in table 2. This basic maneuvering width is that required by the unit to sail safely in very favourable environmental and operational conditions.

Additional widths W_i (to allow for the effects of wind, current etc.) are added to the basic maneuvering lane width WBM to give the maneuvering lane WM, then additional widths for passing distance and bank clearance are added to determine the total channel width. The additional widths are given in tables 2 through 4.

3. Navigation in bends

Units navigating around bends are subject to a centrifugal force FZ, which is compensated by a cross-hydrodynamic force (FR) caused by pressure and suction fig. 3. FZ depends on the relative speed to the ground, bend radius, mass and added mass while FR depends on speed through water, under water profile and drift angle. These units require a swept track while turning greater than their breadth [8].

The swept track can be calculated from the eq. [8]:

$$WS = \sqrt{(R_i + B)^2 + \left[\frac{1}{2}L + (R_i + \frac{1}{2}B).Tan\,\beta\right]^2 - R_i}$$

see fig.4

where,

R_i =inner bend radius

L =ship length

B =ship breadth

β=drift angle

Table 1
Basic maneuvering lane (W_{BM}) [7]

Ship maneuverability	Good	Moderate	Poor
Basic maneuvering lane, WBM	1.3 B	1.5 B	1.8 B

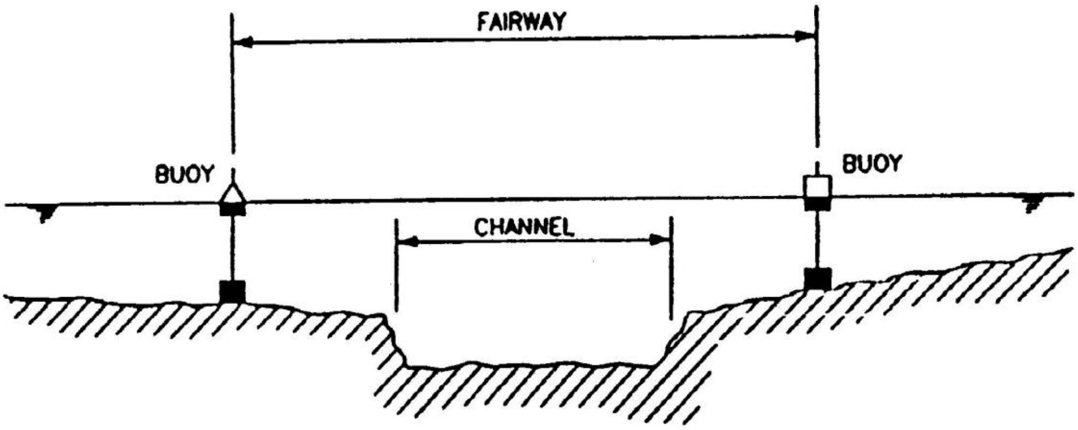

Fig. 1. Channel and fairway definitions.

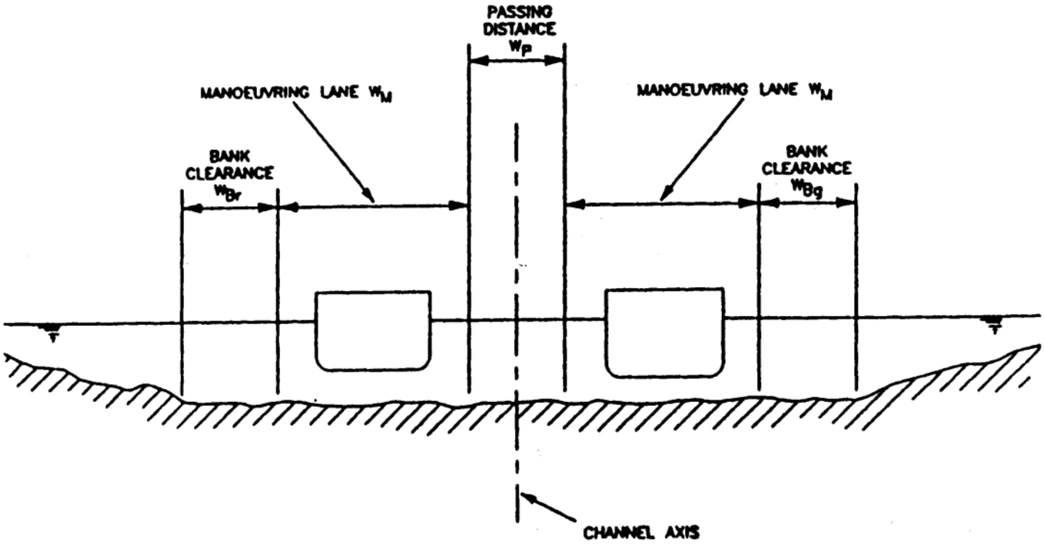

Fig. 2. Elements of channel width.

Table 2
Additional widths for straight channel sections (W_i) [7]

	Vessel speed	Outer channel exposed to open water	Inner channel protected water
(a) Vessel Speed (Km/hr)			
- Fast > 22		0.1 B	0.1 B
- Moderate > 14.5 – 22		0.0	0.0
- Slow 9 – 14.5		0.0	0.0
(b) Prevailing cross wind (knots)			
- Mild ≤ 15 (≤ Beaufort 4)	All	0.0	0.0
- Moderate > 15 – 33	Fast	0.3 B	-
- (> Beaufort 4 - Beaufort 7)	Mod	0.4 B	0.4 B
	Slow	0.5 B	0.5 B
- Severe > 33 – 48	Fast	0.6 B	-
- (> Beaufort 7 - Beaufort 9)	Mod	0.8 B	0.8 B
	Slow	1.0 B	1.0 B
(c) Prevailing cross current (knots)			
- Negligible < 0.2	All	0.0	0.0
- Low 0.2 – 0.5	Fast	0.1 B	-
	Mod	0.2 B	0.1 B
	Slow	0.3 B	0.2 B
- Moderate > 0.5 – 1.5	Fast	0.5 B	-
	Mod	0.7 B	0.5 B
	Slow	1.0 B	0.8 B
- Strong > 1.5 – 2.0	Fast	0.7 B	-
	Mod	1.0 B	-
	Slow	1.3 B	-
(d) Prevailing longitudinal current (knots)			
- Low ≤ 1. 5	All	0.0	0.0
- Moderate > 1.5 – 3	Fast	0.0	-
	Mod	0.1 B	0.1 B
	Slow	0.2 B	0.2 B
- Strong > 3	Fast	0.1 B	-
	Mod	0.2 B	0.2 B
	Slow	0.4 B	0.4 B
(e) Significant wave height Hs and length (m)			
- Hs ≤I and ≤ L	All	0.0	0.0
- 3 > HS > I and = L	Fast	~ 2.0 B	
	Mod	~ 1.0 B	
	Slow	~ 0.5 B	
- HS > 3 and > L			
	Fast	~ 3.0 B	
	Mod	~ 2.2 B	
	Slow	~ 1.5 B	
(f) Aids to navigation			
- Excellent with shore traffic control		0.0	0.0
- Good		0.1 B	0.1 B
- Moderate with infrequent poor visibility		0.2 B	0.2 B
- Moderate with frequent poor visibility		≥ 0.5 B	≥ 0.5 B
(g) Bottom surface			
- If Depth ≥ 1.5 T		0.0	0.0
- If Depth < 1.5 T then			
- Smooth and soft		0.1 B	0.1 B
- Smooth or sloping and hard		0.1 B	0.1 B
- Rough and hard		0.2 B	0.2 B
(h) Depth of waterway			
- ≥ 1.5 T		0.0	≥ 1.5 T 0.0
- 1.5 T – 1.25 T		0.1 B	< 1.5 T – 1.15 T 0.2 B
- < 1.25 T		0.2 B	< 1.15 T 0.4 B
(i) Cargo hazard level (table(5))			
- Low		0.0	0.0
- Medium		~ 0.5 B	~ 0.4 B
- High		~ 1.5 B	~ 0.8 B

Table 3
Additional width for passing distance in two – way traffic (W_P) [7]

	Outer channel exposed to open water	Inner channel protected water
Vessel speed (Km/hr)		
- Fast > 22	2.0 B	-
- Moderate > 14.5 – 22	1.6 B	1.4 B
- Slow 9 – 14.5	1.2 B	1.0 B
Encounter traffic density(table(6))		
- Light	0.0	0.0
- Moderate	0.2 B	0.2 B
- Heavy	0.5 B	0.4 B

Table 4
Additional width for bank clearance (W_{Br} or W_{Bg}) [7]

	Vessel speed	Outer channel exposed to open water	Inner channel protected water
Sloping channel edges and shoals:			
	Fast	0.7 B	-
	moderate	0.5 B	0.5 B
	slow	0.3 B	0.3 B
Steep and hard embankment structures:			
	Fast	1.3	-
	moderate	1.0 B	1.0 B
	slow	0.5 B	0.5 B

Table 5
Determination of cargo hazard level [7]

Category	Cargo
Low	Dry bulk break bulk, containers, passengers, general freight, trailer freight
Medium	Oil bulk
High	Aviation spirit, LPG, LNG, chemicals of all classes

Table 6
Determination of traffic density [7]

Category	Traffic density (vessels/hour)
Light	0 – 1.0
Moderate	> 1.0 – 3.0
Heavy	> 3.0

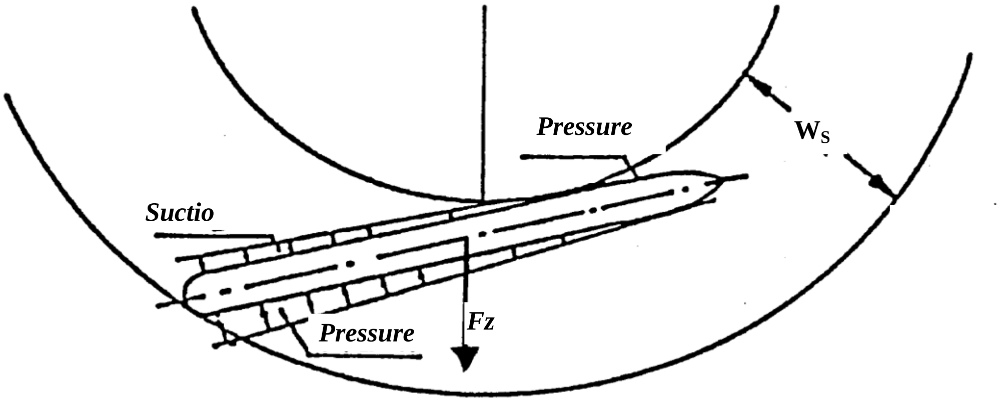

Fig. 3. Forces acting on a ship sailing around a bend.

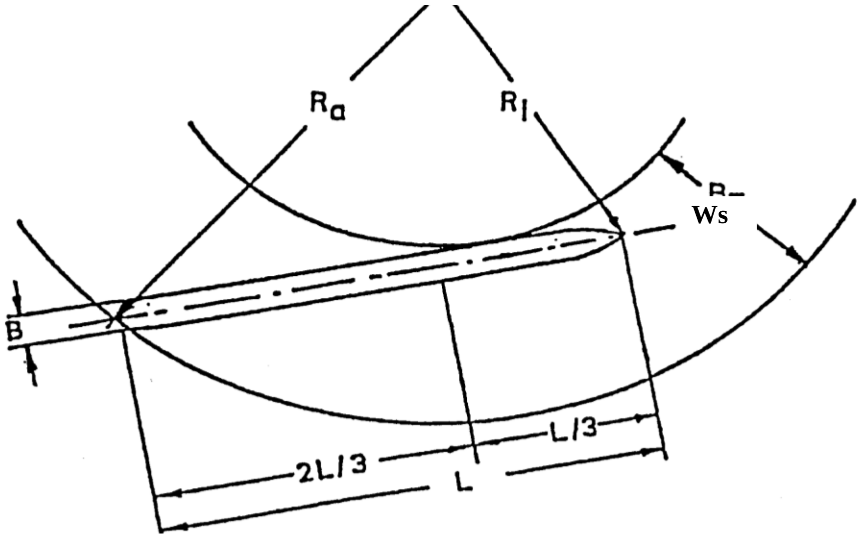

Fig. 4. Bend Radii and swept track.

Relation between bends width and radius, and units' dimensions can be estimated from ship turning data at different h/T ratios if present. Mean rudder angle for the bend should be chosen, and the limiting radius and width read off for a given h/T ratio. Ships having average to good maneuverability with an initial radius of about 2 to 3 ship lengths in deep water the turning radius increases up to 5 or more ship lengths at h/T = 1.10 [7, 9].

Preserving that different ships have almost the same tendency towards the shallow water effect, therefore figs. 5 and 6 can be used for determining the minimum allowable bend radius and basic maneuvering lane width in the preliminary design stage. Further corrections to the basic maneuvering lane due to current, wind.... etc, is performed as in the case of navigation in straight sections. It should be noted that the data in figs. 5 and 6 is for a single screw container ship of lower block coefficient and consequently worse maneuvering characteristics compared to inland units having higher block coefficients.

In case of S shaped bends, the canal should be realigned to have the shape of two bends connected by a straight leg, where the straight leg must have at least a length of 5L, where L is the length of the longest unit under consideration.

Therefore, the way a ship turns depends mainly on h/T; this affects both the radius of turn and width of swept track. As shown in figs. 5 and 6, at the lowest h/T the bend radius has reached its maximum and the width of the swept track its minimum. In calculating the bend radius and width, it is inadvisable to use hard-over rudder angles; this will give no reserve rudder angle. In the preliminary design stage it is suggested that turning radii and swept track width for the designed ship at a steady rudder angle less than hard-over (25-30 rudder angle) be used to preserve a bigger margin for safety.

Keeping position on a bend requires that it will be well marked. In one-way channel, marks on the inside of the channel are better visual cues with minimum of three: one at the apex, one at entry, and one at exit.

If in traffic studies, it becomes apparent that passing on bend is unavoidable, then a separate detailed study will be required for each bend. Cross wind and current allowances in bends should be made in detailed design phase, but as a guide, the width of navigable channel in the bend should be no less than that of the straight section and, additional width should be placed on the inside rather than the outside of the bend fig. 7.

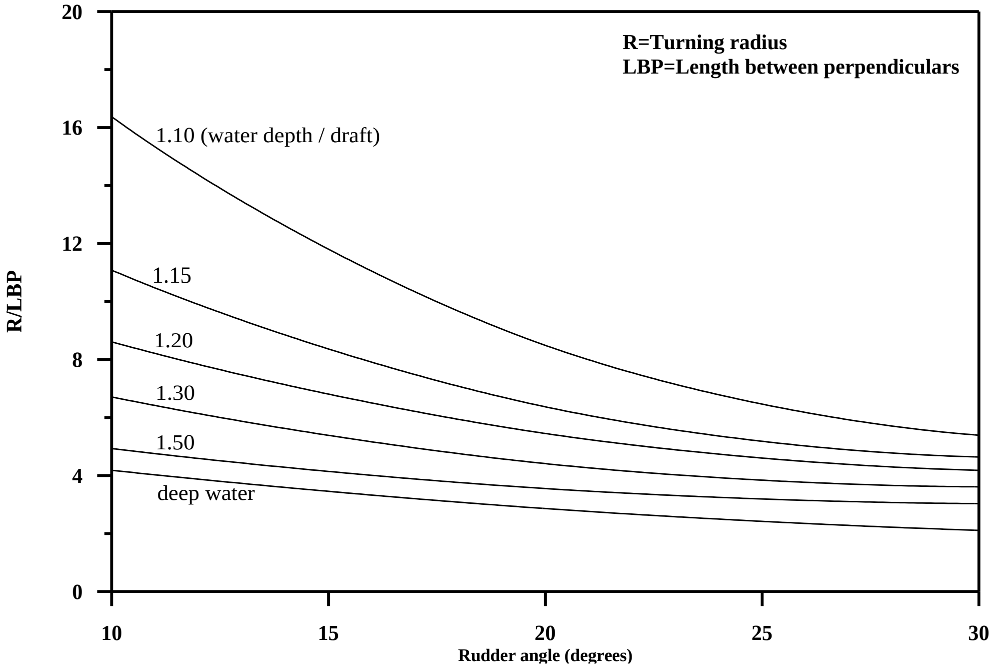

Fig. 5. Turning radius as a function of rudder angle and water depth single screw/single rudder container ship.

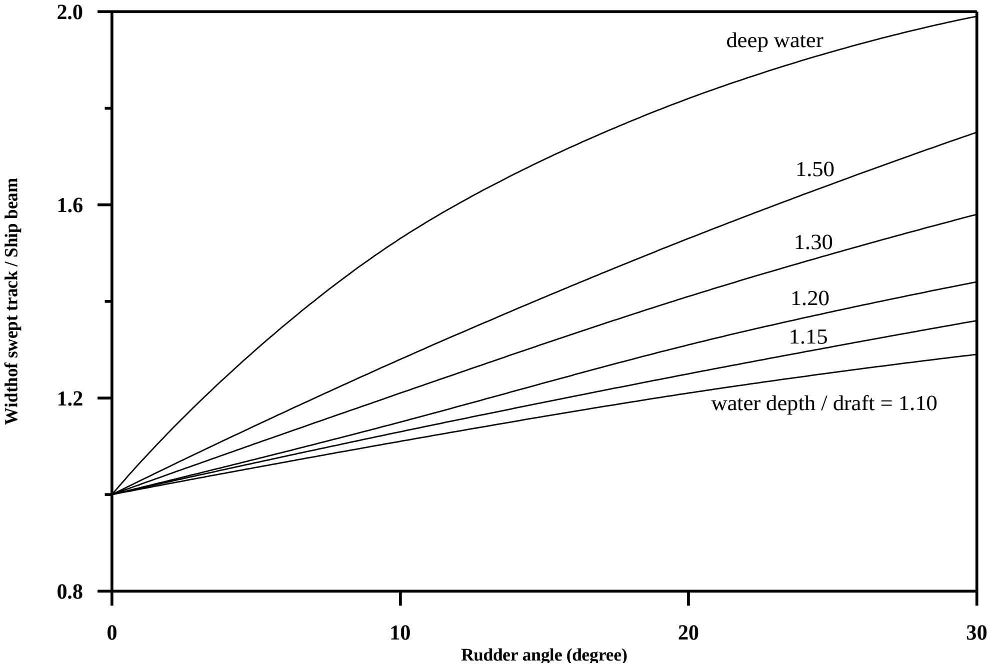

Fig. 6. Width of a swept track in a turn as a function of rudder angle and water depth single screw/single rudder container ship.

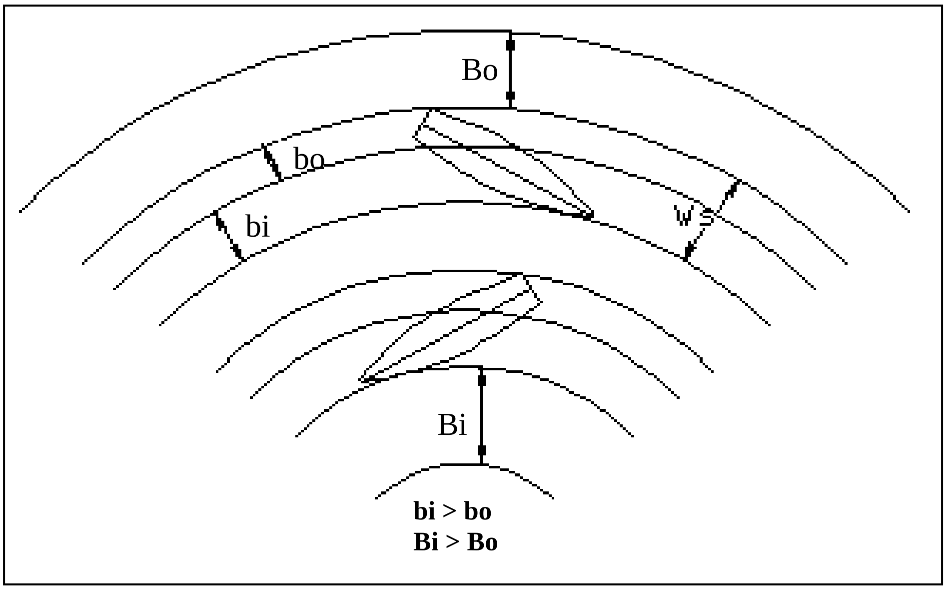

Fig. 7. Additional width in bends.

4. Case study

The current inland fleet in Egypt mainly consists of the types:

Type	L (m)	B (m)	T (m)
Floating hotels	72	15	1.5
Pusher and pushed dumb barges	100	7.5	1.5
Self propelled barges	50	7.5	1.5

These dimensions are nearly fixed due to the size of locks existing on different stretches which have the following dimensions in meters [10]:
In Upper Egypt: 80×16
In Northern Egypt: 110×16

The navigational routes can be divided into three main stretches depending on the type of units navigating each stretch, as follows:
1. Aswan to Luxor: mainly Nile Floating Hotels and some Pushed Convoys, and in the future may extend to include a few Self Propelled units.
2. Luxor to Cairo: mainly Pushed Convoys and in the future may extend to include some Nile Floating Hotels and a few Self Propelled units.
3. Cairo to Alexandria and Cairo to Damietta: Pushed Convoys and Self Propelled units.

The dimensions of the navigational channels in each of the three mentioned stretches will be calculated for two-way traffic (two navigational lanes and prohibiting overtaking), two way traffic while permitting overtaking (when no unit is coming in the other direction), and three-way traffic (two units overtaking each other while meeting a third unit).

Assumptions are made for the calculations based on the condition of the navigational canals in the different stretches. The relation between the rudder angle and the canal width in bends and bend radius for pushed convoys and floating hotels are shown in figs. 8 and 9. The minimum inner bend radius according to pushed convoys is 355 m, using a rudder angle of 30 degrees, while Floating Hotels will use a rudder angle of about 15 degrees to navigate around such a bend. The width of the navigational canal in the smallest bend (minimum bend radius) is given in the following calculations for clarification. In case of bends having smaller bend radii, the width of the canal in bend should be increased, and this increased width is to be added on the inside of the canal to increase the bend radius.

The other results obtained from the calculations are given in tables 7 and 8.

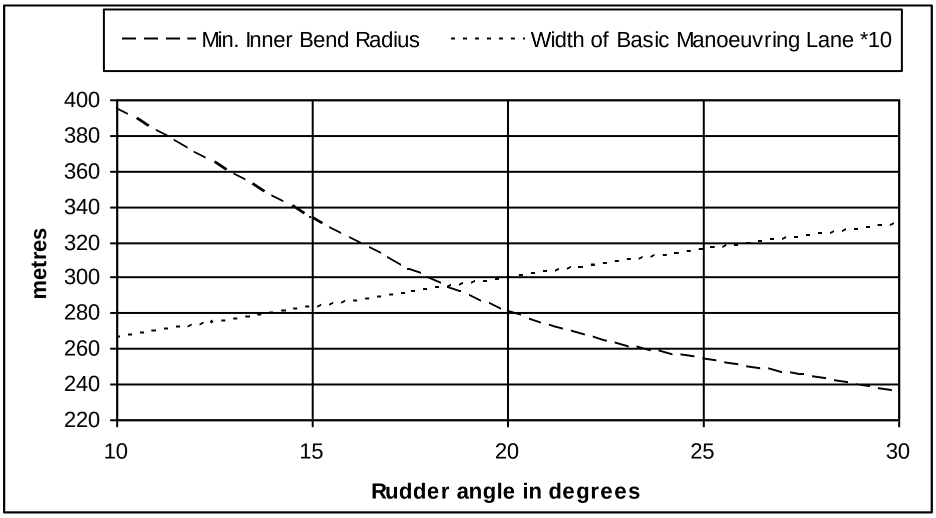

Fig. 8. Width of basic maneuvering lane in bends and turning radius at different rudder angles for floating hotels.

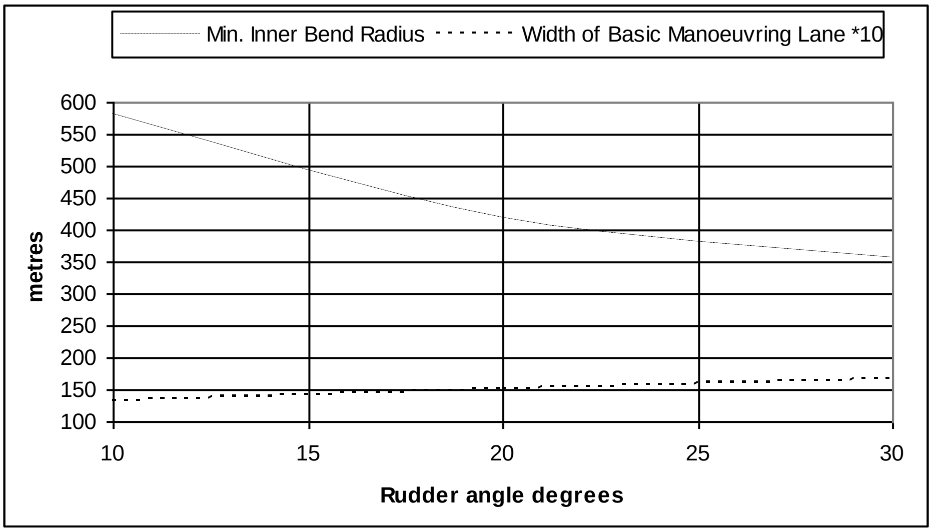

Fig. 9. Width of basic maneuvering lane in bends and turning radius at different rudder angles for pushed convoys.

Table 7
Width particulars pertaining to floating hotels and pushed convoy routes

	Floating hotel	Pushed convoy
Width of main lane in straight sections(m)	27	13.5
Additional width for bank clearance(m)	4.5	2.25
Passing distance during meeting(m)	21	10.5
Passing distance during overtaking(m)	31.5	15.75
Width of main lane in bends having a radius of 355m(m)	28	16.5

Table 8
Total canal width results summary

	Total canal width in straight sections (m)	Total canal width in bends having a radius of 355m (m)
Total canal dimensions for two way traffic, always prohibiting overtaking		
Two floating hotels	84	86
Two pushed convoys	42	48
Total canal dimensions for two way traffic, permitting overtaking when no unit is in the opposite direction		
Two floating hotels	94.5	96.5
Two pushed convoys	47.25	53.25
Total canal dimensions for three way traffic		
Three floating hotels	142.5	145.5
Two floating hotels and a pushed convoy	129	134
One floating hotel and two pushed convoys	111	118
Three pushed convoys	71.25	80.25
Total canal dimensions for four way traffic of pushed convoys		
	100.5	112.5

The details of the case study and its results are given in ref. [11].

5. Conclusions

According to the calculated dimensions of the navigational canal and the current overall dimensions of the existing canals, the best alternatives for the navigational canals dimensions of the three stretches are:

5.1. Aswan – Luxor

As floating hotels and pushed convoys are the main units navigating this stretch, a canal width of 94.5 m in straight sections should be adopted to allow for three way traffic of pushed convoys and two way traffic of floating hotels while permitting overtaking. However, as the intensity of traffic of floating hotels in this area is rather high at particular time of the day (many ships leave at nearly the same time), it would be more advisable to design the navigational canal to allow for three way traffic of floating hotels with a width of 142.5 in straight sections.

5.2. Luxor – Cairo

As an increased number of pushed convoys and fewer floating hotels will navigate this stretch, a canal width of 111 m in straight sections should be adopted to allow for four way traffic of pushed convoys and three way traffic consisting of 2 pushed convoys and a floating hotel.

5.3. Cairo - Alexandria

Only pushed convoys and self propelled units will navigate this stretch and as the width of the canal is limited in ElNobariya canal then this stretch will be subdivided into two sub stretches Cairo-Boulin via Beheiry canal and Boulin-Alexandria via Noubariya canal. In Cairo-Boulin a canal width of 71.25 m in straight sections should be adopted to allow for three way traffic of pushed convoys or self propelled units. Since in Boulin-Alexandria, the locks are not so distant from each other then overtaking can be prohibited, and a canal width of 42 m in straight sections should be adopted to allow for two way traffic of pushed convoys or self propelled units prohibiting overtaking.

For pushed convoys, bends having bend radius greater than 580 m will have the same width as straight sections, while for floating hotels, bends having bend radius greater than 380 m will have the same width as straight section. The width of the canal in bends having smaller bend radii should be considered for each of them separately, and can be calculated using figs. 8 and 9.

Recommendations of having straight legs of at least a length of 5L connecting S shaped bends should be followed.

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