4.6 Scaled Manned Models

Nigel Allen and Arthur de Graauw

The goal of scaled manned model training is to gain a better understanding of ship handling behaviour through a combination of theoretical and practical knowledge, enabling safer practice in ports worldwide.

Scaled manned models are a proven method of training in ship handling for pilots, as recognised by the IMO in A.960 (23) *'Recommendations on training and certification and operational procedures for Maritime Pilots other than Deep Sea Pilots'*:

> *"5.2 (initial training... both computer and manned model), and*
>
> *5.5.6 (updating and refresher training ... courses in ship handling training centres using manned models), and also*
>
> *6.1 that recommends continued proficiency and updating of knowledge be undertaken at intervals not exceeding five years".*

IMO STCW Code (Annex Chapter II) Table A-II/1 (Page 48) Column 2 lists 18 scenarios of *'Knowledge, understanding and proficiency'* and Column 3 *'Methods of demonstrating competence'*, includes scaled manned models:

> *"Examination and assessment of evidence obtained from one or more of the following:*
>
> 1. *Approved in-service experience*
> 2. *Approved simulator training, where appropriate*
> 3. *Approved manned scale ship model, where appropriate".*

Importantly, scaled manned model training works and is a course that mariners thoroughly enjoy, as testified by the many participants over the years.

It is recognised that safe handling of ships depends on many factors, such as but not restricted to:

- A ship's manoeuvring characteristics
- human factors (operator experience and skill, their behaviour in a stressful situation, etc)
- actual environmental conditions
- the degree of water area restriction (channels and depths) and confined areas.

Courtesy of Port Ilawa, Poland

Figure 1 - Manned models in action

Research has shown that human error and poor controllability of ships contribute to collisions, rammings and groundings, so this type of training is invaluable in improving ship safety. Control of ships is a proven teachable skill with scaled manned models.

History

Scaled manned model training first appeared at Port Revel, France in 1967, followed by Warsash Maritime Academy (WMA) at Marchwood Lake, UK and at Lake Ilawa, Poland, both in 1980. There are also established scaled manned model training centres at Port Ash, NSW, Australia, at Great Herring Pond, Massachusetts Maritime Academy, USA, and at Port St Tammany, Louisiana, USA.

Scale model ships have and are still being used for research purposes, mostly in towing tanks. The idea of having them manned dates back to the 1960s and, with ship size increasing rapidly from around that time, the idea of using scaled models for ship handling training was born.

Courtesy of CTO, Gdansk, Poland

Figure 2 - Pods with steerable flaps

Initially, this type of training was undertaken by Masters, but over the years pilots have increasingly become the major users.

Scaled manned models are a form of simulation that is complementary to computer based simulator training, which relies on complex algorithms to simulate vessel motions in a seaway. The complexity when manoeuvring in restricted waterways is challenging to reproduce, particularly when numerous vessels are very close to one another. Scaled manned models do not have this restriction as, due to the laws of similitude, a scaled model will automatically and faithfully reproduce the forces experienced in real life.

Real-time electronic bridge simulator training reproduces the bridge environment and is best suited to bridge resource management and collision avoidance training, while scaled manned models more accurately reproduce manoeuvres with currents, waves, tugs, anchors, bank effects, etc and are best suited to ship handling training.

There are four basic components to a scaled manned model centre:

1. Scaled ship models.
2. A lake.
3. Teaching and course content.
4. Students.

4.6.1 Scaled ship models

The Similitude Law of William Froude (1810 – 1879) is used to design appropriate scaled manned models, which means that gravity is considered to be preponderant over the other forces acting on the hull (viscosity, capillarity, cavitation, compressibility, etc).

Similitude of shape

The model has exactly the same geometric shape as the real ship. This means that all the length (L) dimensions of the real ship are divided by the same factor, the scale factor. Commonly, a scale (S) of 1:25 is chosen, so:

$S_{(L)} = 25$ (smaller, hence distance is 25 times less)

It should be noted that, in this similitude, the proportions are kept (the ratios between the various dimensions of the ship are identical). This is also the case with the block coefficient. Furthermore, the angles are a length ratio, so they are also identical to the original ones. The scale factors of the areas and volumes are deduced from this, ie:

$S^2_{(L)} = 25^2 = 625$

$S^3_{(L)} = 25^3 = 15{,}625$

Similitude of mass (M)

The model used for ship handling training must not only resemble the original but also move in the same way as the original when subjected to similar forces. Consequently, the scale factor for the mass (M) and displacement is the same as that for the volumes, ie:

$S_{(M)} = S^3_{(L)} = 25^3 = 15{,}625$

Similitude of forces (F)

If the external forces on the model are in similitude, like the shapes, masses and inertia, the model's movement will be in similitude. It can thus be shown that the forces (F) must be at the same scale as the masses (M) and weights, so:

$$S_{(F)} = S_{(M)} = 25^3 = 15{,}625$$

Similitude of speed (V)

In agreement with Froude's Law, which states that $V/\sqrt{gL}$ is equal on model and also in nature, the velocity scale is the square root of the length scale, so:

$$S_{(V)} = S_{(L)}^{1/2} = \sqrt{25} = 5 \text{ (times slower than real life)}$$

Similitude of time (T)

Time is a distance (L) over speed (V), so:

$$S_{(T)} = S_{(L)}/S_{(V)} = S_{(L)}^{1/2} = \sqrt{25} = 5 \text{ (times faster than in real life)}$$

Similitude of power (P)

As the power $P = F \times V$, hence

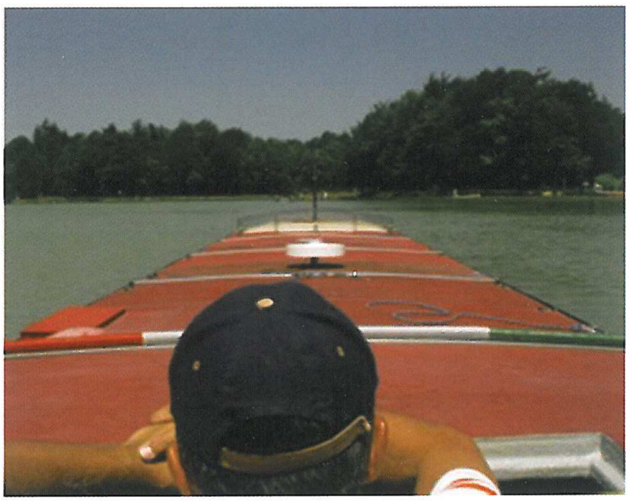
$$S_{(P)} = S_{(F)} \times S_{(V)}, \text{ so:}$$

$$S_{(P)} = S_{(L)}^3 \times S_{(L)}^{1/2} = S_{(L)}^{7/2} = 25^{7/2} = 78{,}125$$

In conclusion, by choosing a scale of 1:25 for the lengths and by complying with Froude's Law, a model 25 times smaller can be built, operating 5 times more slowly. However, as the distances are 25 times less, things occur 5 times faster. The ships are 78,125 times less powerful.

Similitude of manoeuvre

While the models must be in correct similitude, this is not enough. Other factors can affect the correct reproduction of the manoeuvres, such as the field of vision, onboard equipment and wind.



Courtesy of Siegberto Schenk, Brazil

Figure 3 - Pilot's view from the bridge

It should be noted that manoeuvres on a model require the same pilot's orders as those on a real ship. The only difference is that they are executed five times faster on the model, so there is no time to discuss them. This encourages responses to become intuitive but based upon a pre-assessed but flexible plan. What feels to be a crisis on day 1 of a manned model course becomes routine by days 3+, which has to be a good definition of training.

As far as the wind is concerned, as the speed scale factor is 1 in 5, a wind of 10 knots on the lake is equivalent to 50 knots wind force on the model. Manned model sites are very carefully selected for good shelter from the wind, so that uncontrollable wind effects are minimised.

Despite these factors, 40 years of experience has shown that trainees quickly master these scaling factors and treat the models as though they are real ships.

The pilot's position gives him a true field of vision from the bridge. He gives his orders to the helmsman, who is seated in front of him and operates the wheel and engine. Some models allow the pilot to have the controls so he can manipulate them directly. Scaled manned model exercises promote good situational and spatial awareness, a lack of which contributes to most accidents and incidents.

Courtesy of Warsash Maritime Academy Ship Handling Centre at Timsbury Lake, UK

Figure 4 - Manoeuvring a scaled manned model

Many models are fitted with lateral thrusters and operational anchors. Scaled model tugs are also widely used to assist in manoeuvres.

Instrumentation in a model varies from very basic to a full set which, in some cases, shows real ship speed and not actual speed on the lake. Clearly, each centre has its own ideas and budget limitations.

All encourage their trainees to use their eyes to receive all the visual cues around them and this can be reinforced by relevant instrumentation, which in practice is how it is on a real ship.

Courtesy of Port Ilawa, Poland

Figure 5 - Helmsman position

External rudder and engine command indicators are sometimes fitted as these assist an instructor when observing a manoeuvre.

Most centres operate oil tankers, gas carriers, container ships, ferries and podded ships, usually representing real ships with their corresponding characteristics. The rudder and engine response times are respected and are adjustable, as is the 'power' of the engine, to reproduce the characteristics of turbine or diesel engine propulsion.

Ship validation is conducted for each model ship both on the lake by means of typical manoeuvres (turning circles, measured miles on different engine settings and crash stops) to be compared with the corresponding real ship, and by means of expert assessments performed by the pilots and Masters using the real ship.

A more recent innovation is the use of a controllable pitch propeller (CPP) on a scaled model, which has proved successful.

Some centres also have scaled model tugs that are radio controlled or manned, which work very effectively. They also give pilots an opportunity to experiment using tugs in different ways.

Courtesy of Port Revel, France

Figure 6 - Emergency steering with Escort tug indirect

Tracking systems can be used to replicate an ECS (electronic chart system) on board to record manoeuvres. Unfortunately, in some cases the trees around a lake can interfere with GPS satellite reception, rendering the quality of tracking poor.

The advantages of using scaled manned models can be summarised as;

- Experimentation can be carried out without fear of consequences
- automatic and faithful reproduction of hydrodynamic effects
- realism of manoeuvres, especially in emergency situations
- real environmental effects that can be felt
- realism of multi ship manoeuvres, eg interaction
- use of anchors, such as dredging
- instant learning environment, where things can quickely be determined as to their effectiveness and whether or not they work
- explanations are made immediately after an exercise in the debrief
- high ratio of lecturers to trainees
- helps in developing strategies when planning real life manoeuvres
- scaling effects permit many more exercises to be undertaken when compared to real time, hence time and cost efficient.

4.6.2 The Lake

A 'perfect' manned model lake might have the following:

- An area of deeper water (over 4 times the draught) to display the behaviour of ships, with special regard to turning circles and stopping distances
- shallower water (less than twice the draught) to display increased turning circles and stopping distances. Extreme shallow water (10 – 20% UKC) to replicate the difficulties experienced while manoeuvring and the associated hydrodynamic effects.

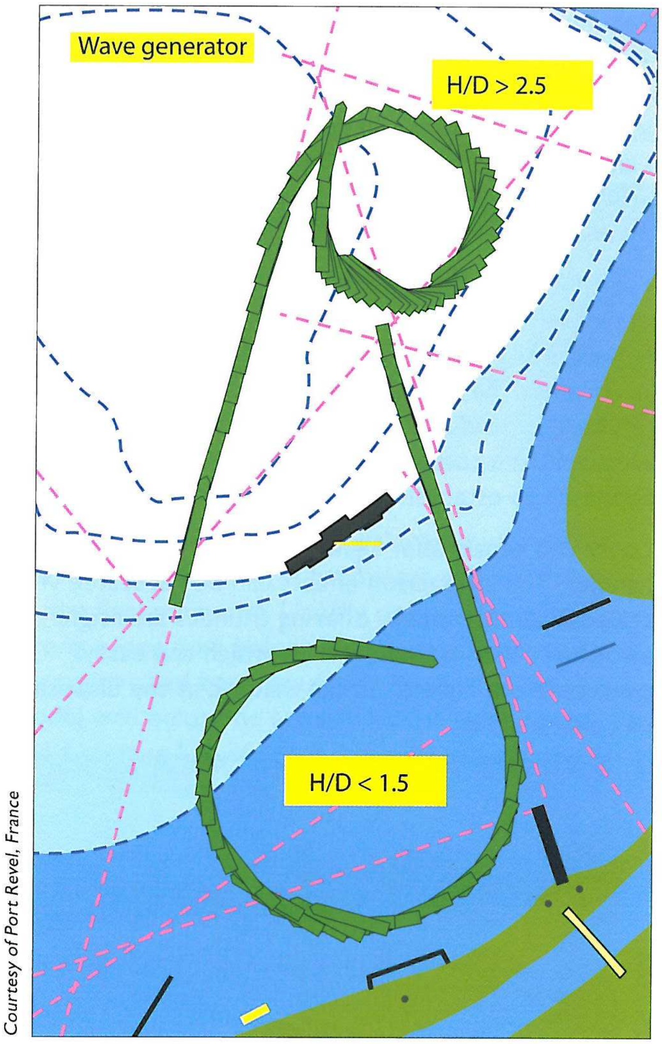


Figure 7 - Tracks of turning circles in deep and shallow water

A constant water level and an ability to drain the lake periodically will assist in maintaining the correct bottom profile in relation to the draughts of the models.

Shelter from wind is probably the most important aspect of any scaled manned model lake due to the exaggerated factor of the effect of the wind on the models. This can be achieved by choosing a site that has light winds during the operating season and by having a natural screen (in any direction), which is usually provided by large mature trees (that remain under the management of the lake site). That way, even on very windy days, realistic scaled manned model manoeuvres can still be carried out successfully. However, exposing students to strong wind conditions is also useful as part of the training, especially for emergencies.

A variety of challenges are required for junior personnel, as well as for very senior personnel on repeat 5 year courses, to satisfy initial ship handling training and updating and refresher training. Ideally, a site of around 10 acres (4 hectares) is required to provide different configurations of berths, canals, channels, depths and restricted areas.

To represent berths found around the world, and all the associated hydraulic effects, a wide variety of berths are needed, eg. solid and open berth structures. The ability to construct temporary berths can be very useful in trying to copy a particular scenario for a customer trying different methods of approach to establish what works.

Locks and canals offer significant challenges to a ship handler. The interaction effects can be replicated with scaled manned models, offering trainees an insight into the power of these forces, which can easily overcome the control forces that are at the disposal of a ship handler.

Courtesy of Port of St Tammany, USA

Figure 8 - Push barge in canal

Courtesy of Port Ash, Australia

Figure 9 - Ships interacting in a canal

Lake bed material needs to be suitable for anchorwork and free from obstructions.

Current/wave generators can be useful to simulate particular scenarios.

With this type of training, collisions and groundings happen due to the experimental nature of the learning environment. Ideally, the banks of the lake should be of a soft material to minimise any damage to the models, which need to be constructed robustly to take the many knocks and scrapes.

The selection of a site must consider the comfort of the trainees. A site with a temperate climate is preferable. Hours of operation should normally be during the hours of daylight. Some centres have run night exercises, but this generally becomes problematic with resources and next day fatigue. It also requires some form of lighting on the models, channels and buoys.

Strictly speaking, the water should replicate the density of salt water. However, as some harbours are also found in fresh water, a fresh water lake is quite acceptable as long as the ships' draught is reproduced correctly. The ability to regulate the water level and depths is an advantage. The lake needs to remain ice free to enable the models to manoeuvre without any encumbrance. Any weed in a lake may foul propellers, rudders and bow thrusters. Just a small amount of weed can drastically affect the performance of a model, so water that has significant turbidity is beneficial to prevent weed growth. Bottom feeders, such as carp, assist this state. A natural water flow can also generate small currents that vary depending on recent rainfall, which is beneficial to the training of ship handlers as they have to recognise such external effects and learn to respond to them.

4.6.3 Teaching and Course Content

The key to any learning environment is the ability of the teaching staff to communicate with trainees, within a framework that provides a thoughtful and structured learning process.

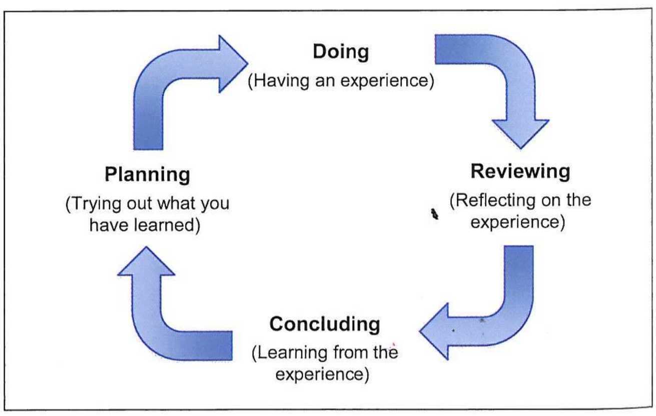


Figure 10 - Kolb's experimental learning style

A strong link with an established academic institution involved in relevant hydraulic research can ensure that teaching methods and course structure are appropriate. However, a good balance is required leaning on the side of practical training.

Trainees generally respond well to being taught by experienced ship handlers, who have a great deal of empathy with the challenges faced by trainees in a wide variety of situations.

For scaled manned model training, standards are set at each facility as there are no international standards for manned models. Standards are, in the main, set high to have an appropriate level of credibility.

Trainees can be chief officers with little or no ship handling experience, to very experienced or highly trained pilots on refresher courses. While course objectives may be similar, the way they are delivered needs to be flexible to ensure that the trainee is thoroughly engaged. Over recent years, a number of specialist manned model training courses have been developed, building upon the 'basic' course, eg azimuthing propulsion, emergencies, offshore, ship types, tugs, twin screw, etc. Further, pilot authorities can often tailor an advanced course to suit their own requirements, perhaps where the ship models can be used in an 'investigative' way.

It is vital that staff receive appropriate training to teach (train the trainer) and an ability to teach should not be presumed just because of vast experience in ship handling. Experience shows that it takes several years to become a really good ship handling instructor.

The high ratio of one staff trainer to two students is the industry norm. The residential nature of these courses encourages extended discussion between course members, where exchanges of views help to consolidate learning.

Typically a basic course involves 20% classroom theory and 80% practical ship handling on the lake. The subjects covered are: scale effects, principles of ship handling (especially the practical use of the pivot point), stopping, turning, wind effects, anchor work (dredging anchors), and interaction (usually in a canal). Depending upon client needs, optional exercises involving bow thrusters and practical shipassist with tugs are often available.

Courtesy of Port Revel, France

Figure 11 - Ooops! Broken bow

Where a ship model contacts the jetty, the trainee tries to explain how this happened, concentrating on the final moments. Usually things were going wrong a long time before the incident happened and the trainee had been struggling to control the ship model well before he actually hit the jetty. Speed and a correct line of approach need to be part of a berthing plan and, frequently, there is no berthing plan. A good debrief will help to identify these types of shortcomings and assist a trainee to think about an appropriate and safe berthing plan, including abort plans.

4.6.4 Students

Students come from around the world with a wide variety of backgrounds, cultures and languages. Trainers need to establish a starting point of basic ability and knowledge (eg can they steer a ship?). Normally, most trainees have attained a senior background level of marine knowledge and experience, upon which a sound knowledge of ship handling can be added. However, some do not and may have a much narrower base of marine knowledge and this has to be recognised and acknowledged. Increasingly, trainees from the commercial yacht industry now attend ship handling courses and have proved to be receptive and successful in this type of training.

It is helpful if there is an even number of students, as two trainees working together will help to reinforce the learning experience.

Courtesy of Massachusetts Maritime Academy, USA

Figure 12 - Tanker model showing trainee positions

From my own perspective

When I trained as a pilot many years ago, the senior pilots that I tripped with had all, to a large degree, figured out what to do, but most could not explain to me why they did things a certain way. I met an old shipmate when he was just 3 days into a manned model course. He was going through his pilot training for another port and, over a couple of beers that evening, I learnt more about ship handling from him than had already been explained to me, and he wasn't even a pilot yet! Importantly, he had already gained a sound understanding of the theory of ship handling and had a good foundation upon which to build his experiences.

I then pestered my harbour master to allow me to attend a scaled manned model course and it was the best course by far that I'd ever attended. Seven years later, I repeated the course as part of my training to lecture at the lake, and I was amazed at how much information had gone over my head on that first course when I was simply grappling with the basics. Now, although recently retired, I am still learning about ship handling through discussions with the many trainees I meet.

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Nigel Allen

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He has participated in two EU marine related projects, MarNIS and AZIPILOT, and a PIANC Working Group on Hydro and Meteo information. He is a Fellow of the Nautical Institute and currently Chairman of their Nominations Committee.

Arthur de Graauw

Arthur de Graauw is a French/Dutch coastal engineer employed by a French consulting firm, SOGREAH (now ARTELIA).

He graduated from Delft University of Technology in 1976 in civil engineering of coastal structures and areas. He has used many hydraulic scale models and mathematical models in his work.

He worked on numerous projects related to coastal erosion, industrial ports and marinas in the Mediterranean area including Lebanon, Gaza, Egypt, Libya, Tunisia and France.

Since 2002 he has managed the Port Revel Ship Handling Training Centre using scaled manned models. He has participated in several EU projects including ETCS and AZIPILOT.