Exploring alternative methodologies in innovative performance yacht design

Robert Shaw, Unitec NZ (AM)

KEY WORDS

Design; methodology; action research; performance yachts.

NOMENCLATURE

CFD	computational fluid dynamics
IMS	International Measurement System
IOR	International Offshore Rule
IRC	Royal Ocean Racing Club international measurement and rating rule
polar	computer-generated performance prediction
VPP	velocity prediction program

INTRODUCTION

Increasingly the dominance of engineering process in yacht design development imposes limitations on the possibilities and scope for creative design. Designers are also limited to some extent by tradition — following what has gone before — as well as being hampered by class and rating rules.

This paper explores an alternative methodological framework for yacht design that has innovation as its central concern. This method has been trialled and developed in the design of the Shaw sport boats and performance keel yachts. It gives due weight to the iterative process, utilising an action research model which affords access to the heuristics of iteration.

TOWARDS A NEW METHODOLOGY

The method presented encourages innovation by blending the empirical knowledge obtained through scientific techniques with experiential wisdom and artistic input. It focuses on meeting the key criteria of user experience, performance and handling characteristics, and how particular aspects of the yacht's specifications, dimensions, construction and fit-out are refined according to the defined design process. It argues that in a field increasingly dominated by mathematical models and computer-based predictions, there remains a powerful role for the harder-to-quantify role of art in the creation of high-performance yachts.

The resulting description and visualisation of this alternative methodology for yacht design aims to encourage and support a degree of understanding and creativity by exploring the complex web of tacit knowledge and explicit principles in a simple, communicative form.

The multifaceted nature of yacht design, informed as it is by theory and practice from various and diverse fields of knowledge, is both challenging and rewarding. However, the range of complex influences and issues required to be worked through to resolve the process into a coherent, successful design is not been well researched or documented.

The designing of yachts has evolved over many centuries and is now acknowledged as an iterative process. In the past 50 years the methods of design and development have become heavily influenced by the engineering discipline, which can stifle the influences of art and creativity in the process.

In the past, yacht designers concentrated on evolving traditional, proven hull, deck and appendage shapes. Yacht designers used a combination of design and building experience, intuition and their "eye" — i.e. what they thought looked good to them — to develop new designs, drawing subconsciously on a range of types of knowledge. Phillips-Birt (1976) describes "the ideal [yacht] designer" as "a magnificent creature who is at once a hydro-dynamist, an aero-dynamist, an engineer, a practical boatbuilder, an experienced seaman under sail, and an artist."

However, with the development of mathematical or computer-based models, including VPPs generating polars, many modern designers have begun to rely more on "science" than "art" to define the parameters of their designs. Yet it is noted by Scarponi, Shenoi, Turnock and Conti (2006) that

> To bear the costs of a close modelling of a sailing yacht, with the purpose of getting accurate VPP predictions, is still far from being an easy task. A numerical approach in terms of Computational Fluid Dynamics can also be regarded as a valuable source of information, but . . . numerical methods can provide just partial responses to designers.

Yacht design methods have come to rely heavily on engineering techniques, which impose limitations on the design process. The limitations of predictive resources has limited the development process to following and refining what has gone before, limiting development to small, incremental changes in the quest for improvement. The speed of development has been further delayed by class and rating rules such as IOR, IMS and more latterly IRC, and by safety requirements. These factors combined have meant advancements in yacht design have been somewhat slow and restricted.

Much current literature concentrates on the engineering and mathematical aspects of yacht design (that is, science). With the development of computer-aided drafting techniques and modelling software with some ability to predict the performance of hulls and appendage shapes, research has concentrated on the fields of aero-hydrodynamics and engineering. Concurrently, yacht design literature has become dominated by works by engineers and academics and lacking in works by practising yacht designers, describing actual design methods and processes. This is perhaps because of concerns about commercial sensitivity and the accompanying desire to keep specific processes "secret" in a competitive environment. Another aspect restricting the availability of detailed explanations of design theory is the inability of many designers to articulate their tacit knowledge in an explicit form; Schön (1988) notes,

> Designers are usually unable to say what they know, to put their special skills and understandings into words. On the rare occasions when they do so, their descriptions tend to be partial and mistaken: myths rather than accurate accounts of practice.

While science can play a significant role in design development, successful yacht design must continue to blend this empirical knowledge with experiential wisdom and artistic input, bringing intuitive processes to the endeavour. As Skene (1937) states,

> It must not be inferred that science is not an important aid in designing any kind of a yacht, but with it must be blended natural genius, imagination and much practical experience in handling and building boats.

This paper defines a new methodology for performance yacht design, blending the disciples of engineering and mathematics with the art of the designer's eye and past experience, design intuition and an inherent sense of what is right.

Design methodology

Experience developing a series of prototype yacht designs prioritising performance through a focus on innovation and refinement has seen development driven through a unique lens. With innovation unrestricted by rating rules in the quest for unmatched performance, the principal parameters are set by size, crew and safety considerations. Shaw Yacht Design has developed several successful new designs, each time refining this approach to achieve unique, performance-focused yachts that are pure of purpose.

With the design of performance-focused yachts, the principal design drivers are centred on accessibility (in terms of cost and ease of construction, and transportability of the finished boat), performance (including quantifiable elements such as speed) and handling characteristics/feel (user experience). An iterative design process examining each aspect is applied to achieve maximum potential when considered against the principal design criteria. The design process is a combination of art, utilising the designer's eye, innate knowledge and experience; and science, with recourse to computer-aided technologies in the fields of engineering and aero-hydrodynamics.

The process of yacht design is complex and draws on a range of knowledge and expertise. The blending of art and science is apparent within the design endeavour but, along with the amalgamation of theory and practice, is not always articulated well by yacht designers. Larsson and Eliasson (1994) concede that "Yacht design is an iterative, 'trial and error' procedure" involving a design spiral, "where the designer runs through all the design steps and then returns to the starting point, whereupon a new 'turn' begins."

The iterative nature of the design process lends itself to action research, as this method accommodates the cyclical process of identifying problems, analysing them and taking action to address issues before evaluating the results and moving into another cycle (Swann, 2002). Each iteration of the process adds to the theory.

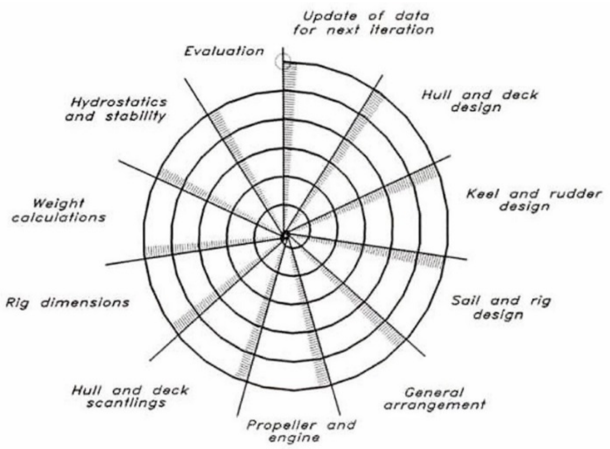

Fig. 1: The yacht design spiral (Larsson and Eliasson, 1994).

A critical component of this design method is the first-hand knowledge and feedback gained through extensive sailing on a range of yachts and primarily on yachts designed through this process. Extensive sailing on these designs, often in a competitive environment, also exposes these designs to critique and unrestricted feedback in the public domain. This extensive verification and analysis forms a critical component of informing the design of future models. As this design method puts a higher value on the designer’s intuition and personal judgement, it is critical that these personal skills be well informed, current and constantly updated.

This designer-led approach to development and refinement is in contrast to the alternative of computational analysis, which does not provide precise feedback on how design variations will manifest in the yacht’s complete sailing performance package. The designer-led approach accepts that the designer must apply his own judgement to achieve a well-balanced, all-round-performing yacht through analysis of the yacht’s variables and complexities. These limitations of computer modelling are noted by several authors, including Levadou, Prins, & Raven (1998), and Roux et al. (2002), who state,

> One of the major difficulties of such a computation [using CFD programs] is that the flow over any one of the components — sails and hull — operating in a real sailing boat is a very complex combination of many phenomena, some of which being clearly non-linear. Besides this, a sailing boat is an integrated system in which sails and hull closely interact.

Larsson (1990) also notes that “A weak point of most [computer] VPPs is the prediction of the performance in waves . . . Waves create effects in all degrees of freedom . . . therefore a complete model for the wave effects is out of reach at present.”

THE ACTION RESEARCH METHOD

The iterative nature of the design process lends itself to action research, as this method accommodates the cyclical process of identifying problems, analysing them and taking action to address issues before evaluating the results and moving into another cycle (Swann, 2002). Each iteration of the process adds to the theory.

The history of action research can be traced to the 1940s; however, many iterations of it have emerged since then. Elden and Chisholm (1993) state that there should be five characteristics present: acknowledging that the researcher is engaged (and therefore may have some bias); focusing on solving real-world problems; the systematic collection of information; the researcher participating in the research problem and process; and the sharing and dissemination of knowledge.

As skills normally associated with trades have become more widely articulated, professionalism has extended to yacht designers. As part of this process the notion of reflection (Doloughan, 2002) has become valued to describe the way in which designers think about and refine their works. Professionalism brought with it the need to justify and defend decisions and this logically led to an emphasis on gathering information and testing practice.

There are a number of challenges to action research as a method, including its incompatibility with some concepts of positivist science (Susman & Evered, 1978; McKay & Marshall, 2001). By its very nature action research values intimate engagement of the researcher in the process and the iterative process, so it is therefore counterproductive to analyse it with reference to a paradigm built on the foundations of neutrality and objectivity.

A further point made by detractors is that there is no tidy definition of action research (Altrichter, Kemmis, McTaggart & Zuber-Skerritt, 2002). While this is a valid comment the reality of the design process itself is that it is intricate and complicated, which therefore makes action research more rather than less attractive as a research method in this instance. Despite these challenges to action research it remains a sound way of illuminating the design process primarily because of the value placed on linking theory and practice (Avison, Lau, Myers & Nielsen, 1999).

Along with the various definitions and explanations of action research there are also many diagrammatical interpretations of the process. For the purposes of yacht design the elements of planning, acting, observing and reflecting illustrated by Zuber-Skerritt (2001) have been used to explain the project. This illustration of the action research cycles interrelates well with the notion of yacht design as a complex, spiral process (as articulated by Larsson & Eliasson, see above).

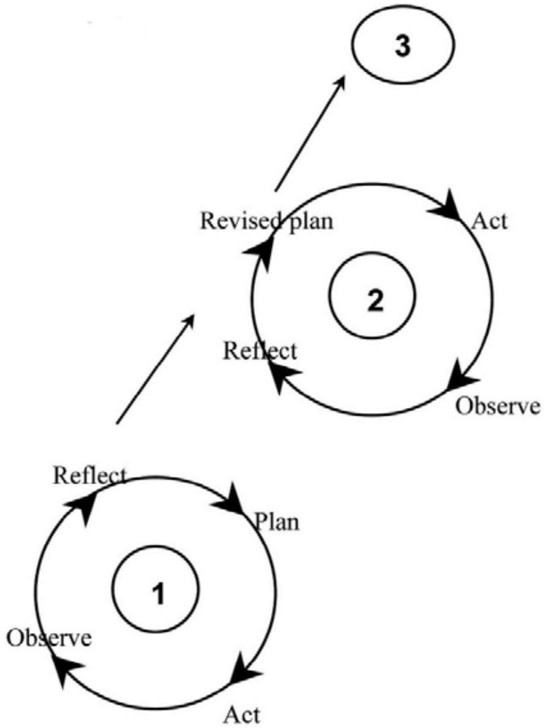

Fig. 2: The action research spiral (Zuber-Skerritt, 2001).

Applying this action research method to yacht design, the Planning phase for each aspect of the design includes identifying current challenges and the foundations of them, including conventional wisdom and limitations on construction and knowledge. The Acting phase is evident in relation to each of the design aspects as a process was put in place to respond to the identified challenge. Observation is apparent in the information that was gathered during the development for each of the aspects — a key step, as the systematic gathering of information is what distinguishes this journey from alternative processes of designing a yacht and contributes research knowledge to the field. Reflection on the action is then used to inform the next iteration of the process.

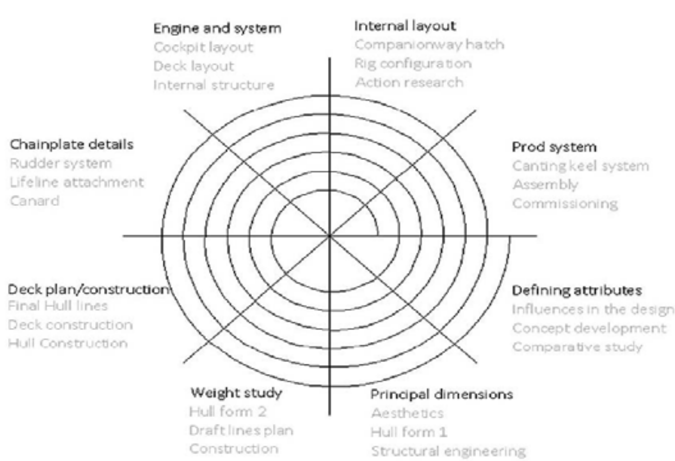

Fig. 3: Design spiral for the development of the Shaw 9 metre.

DESIGN METHODOLOGY IN PRACTICE

Rapid development of performance yachts with limited resources provides a platform for the exploration of the interrelation of art and science in the practice of yacht design. The complexity of a yacht design project, combined with a limitation on time and analytical resources, favour adopting a design method which draws on both intuitive and scientific methods to achieve effective and creative solutions.

Through applying this alternative approach to the yacht design process, within the established framework of the action research spiral, the potential is created to achieve a more unique and possibly more favourable outcome. Skene (1937) notes,

Originality based on one’s own study and experimental work is really the keynote of success. He who does things in a certain way because others are doing it and have always done it that way contributes little to the advancement of the art.

This design method can be applied to the design development of any yacht. While the pure design elements remain unchanged and assist the creative process, some adaption is necessary in specific areas. Safety is always a major design consideration in any yacht, large or small. However, as yachts increase in size more emphasis needs to be placed on the safety of the crew due to the increased loads generated. For example, if a mainsail fails under load on a small boat and the unsupported boom fell to the deck, the risk of injury to a crew member or serious damage to the boat is minimal. If this scenario was repeated on a larger yacht the risk to the crew and the boat is very high and could result in death. The consideration of the dangers of dealing with such high loads must be followed through in all aspects of a design including structural considerations, sails, sheets, hardware, rig design and hydraulics.

Another area that requires variable consideration is related to the yacht’s draft. In the case of smaller yachts, draft is a relatively minor consideration and is most often limited by identifying a practical balance between righting moment, hydrodynamic considerations and any local draft restrictions. However, as the size of yachts increase, draft becomes a major consideration as considerable draft is required to provide adequate righting moment to balance the increased sail plan; yet this can easily become unwieldy and impractical in terms of transporting the boat and use of marina and port facilities. Therefore the use of all available technologies must be explored, to maximise righting moment without excessive draft and enable entry to reduced-draft facilities.

Developing the overall concept design through refining each specific design aspect involves engaging with the action research model described above: planning a design action, acting on that, observing the effects of that plan on the design, and reflecting on how each aspect could be altered and improved in a further iterative spiral. This process underpins a design journey which takes the form of a long, detailed and evolving spiral. A number of key elements in the design are identified and the design process, production and results are presented to give insight into the journey.

This type of design development process lends itself well to the practice of iterative design and engineering. This can be a great benefit by potentially speeding up the delivery time from project conception through design and engineering development, to construction and delivery.

The overall aim of this method is to consider yacht design development through an alternate lens: the approach of shifting the focus of development and decision-making away from a reliance on science-based predictive tools and putting the responsibility for making decisions back on the designer. While the designer is still informed by the use of all available tools and technology, there is a recognition that the designer guided by these tools has superior judgement when making critical decisions.

Design drivers

The design development follows an iterative design development process, from the initial concept design through to final design and construction, covering the consideration of aesthetics, hull and deck form, appendages, and rig and sail dynamics. Each of these are assessed in terms of their impact on the key considerations of usability, performance, and handling characteristics.

The objective to bring creativity to the fore in the design and development process, complemented by specific engineering expertise, brings a shift in the development focus from the science-based, tangible drivers such as compliance to regulations and physical characteristics to less tangible concepts such as user experience and feel (see Fig. 4). Framing the yacht design problem and objectives in this context changes the order of priority by putting the human experience first and requiring the engineering requirements to follow and adapt to or inform these, rather than drive them.

TANGIBLE	**INTANGIBLE**
Project objectives	Deceleration into waves
Development method	User experience
Componentry	Performance
Hydrostatics	Fluid dynamics
Physical characteristics	Feel

Fig. 4: Tangible and intangible aspects of the design process. This chart shows how aspects of both art and science are utilised in the process.

Usability

A key and defining design objective with a performance yacht is usability. By placing a focus on usability, attention must also be paid to safety considerations, especially in the management of high loads when in sailing configuration. A yacht cannot merely be fast in terms of straight-line speed; if it is difficult for the crew to extract this performance or the boat is uncomfortable and inconvenient to sail well then the design cannot be considered successful or to have fulfilled its purpose.

Fig. 4. Shaw 12 metre cruiser-racer *Blink* sets a record across the Cook Strait. (Photo: Chris Coad)

Performance

The second important objective is the yacht's performance, the overall aim being to produce a very high performance yacht, with good all-round abilities in a wide range of conditions, both wind strengths and true wind angles. This is measured in terms of observed performance and race results once the boat is launched. However, Skene (1937) states:

> The problem of designing a sailing yacht with speed as a foremost consideration is a most complex one. External conditions to which a yacht is subject, such as force and direction of wind, condition of sea, etc., are constantly changing so that the attainment of a given speed may not be sought, but rather such a form as shall be easily driven at all speeds within appropriate limits . . . A harmonious adjustment between power and resistance should be sought.

Handling characteristics/"feel"

The third aspect is less tangible: the yacht's handling characteristics and the experience it provides the user in terms of its "feel" and ease of use when being sailed. This cannot be quantified and scientifically described but can be observed once that yacht has been launched. This aspect is therefore informed by science and engineering but in terms of analysis falls more in the realm of "art".

CASE STUDY: SHAW 11 METRE *LITTLE NICO*

The development of the Shaw 11 metre *Little Nico* provides a platform to both explore and evaluate this alternative methodology in practice. The objectives for this yacht in terms of performance was to produce a fast, manageable inshore yacht with good speed in a range of conditions and on all points of sail. There were to be no concessions in the design to appease handicap or rating rules.

Following its launch, the Shaw 11 metre comprehensively won its first regatta on both line and handicap. Since then she has also performed with distinction in club racing, winning races early on and quickly being pushed up into the A1 division, where she has to compete on the water against the likes of TP52s.

The Shaw 11 metre has proved to be well-behaved and easy to handle in a wide range of conditions, with no noticeable vices or areas of reduced performance. The yacht has been sailed extensively over short harbour courses, including windward-leeward courses and has proved easy to handle by a crew of five to seven.

Over time some aspects of the deck gear and setup have been refined, including the addition of further sails to the wardrobe to enhance performance on particular points of sail, including a code zero reaching sail. Significantly, however, all other aspects of the yacht have remained as originally designed.

Fig. 5. Shaw 11 metre *Little Nico* sheets on upwind for the first time on its maiden voyage. (Photo: Michael Chittenden)

CONCLUSION

The development of a range of performance-oriented yachts has provided an opportunity to explore an alternate design development methodology. Softening the focus on the quantifiable sciences, and placing more faith in the designer's own knowledge, brings the potential for greater creativity.

The process emphasises the need to observe and reflect, to consider conventional wisdom and explore ways of expanding it, drawing on a balance of science (mathematical- and computer-driven processes) and art (intuition, past experience and the "designer's eye").

Figure 6. Shaw 11 metre *Little Nico* powers away downwind on Sydney Harbour. (Photo: Michael Chittenden)

The action research method and use of a design spiral methodology has proven benefits and compatibility with yacht design. Focusing on the key considerations mentioned above, each aspect of the design, from the concept development stage, are examined and developed using the process of planning, acting, observing and reflecting, leading on to the next iteration of each aspect and its development.

Despite increased reliance on computer modelling and velocity prediction, the role of the designer's intuition is perhaps more important than ever. Innovation in performance yacht design can only be achieved by exploring all methodologies and drawing on the strengths of each to complement and complete a design.

REFERENCES

Altrichter, H., S. Kemmis, R. McTaggart & O. Zuber-Skerritt, 'The concept of action research.' *The Learning Organization*, 9 (3), 2002.

Avison, D., F. Lau, M. Myers, P.A. Nielsen, 'Action research.' *Communications of the ACM*, 42 (1), 1999.

Doloughan, F.J., 'The language of reflective practice in art and design.' *Design Issues*, 18 (2), 2002.

Elden, M. & R.F. Chisholm, 'Emerging varieties of action research: introduction to the special issue.' *Human Relations*, 46 (2), 1993.

Larsson, L. & R.E. Eliasson, *Principles of Yacht Design*. London, UK: Adlard Coles, 1994.

Larsson, L. 'Scientific methods in yacht design.' *Annual Review of Fluid Mechanics*, 22, 1990.

Levadou, M.M.D.. H.J. Prins & H.C. Raven, 'Application of advanced computational fluid dynamics in yacht design.' Paper presented at the 15th International HISWA Symposium on Yacht Design and Yacht Construction, Amsterdam, 1998.

McKay, J. & P. Marshall, 'The dual imperatives of action research.' *Information Technology and People*, 14 (1), 2001.

Phillips-Birt, D., *Sailing Yacht Design* (3rd ed.). London, UK: Adlard Coles, 1976.

Roux, Y., S. Huberson, F. Hauville, J. Boin, M. Guilbaud, & M. Ba, 'Yacht performance prediction: towards a numerical VPP.' Paper presented to the High Performance Yacht Design Conference, Auckland, 4–6 December 2002.

Scarponi, M., R.A. Shenoi, S.R. Turnock, & P. Conti, 'Interactions between yacht-crew systems and racing scenarios combining behavioural models with VPPs.' Paper presented to the 19th International HISWA Symposium on Yacht Design and Yacht Construction, Amsterdam, 13–14 November 2006.

Schön, D.A., 'Designing: rules, types and worlds.' *Design Studies*, 9 (3), 1988.

Skene, Norman, *Elements of Yacht Design*. New York, NY: Kennedy Bros, 1937.

Susman, G.I. & R.D. Evered, 'An assessment of the scientific merits of action research.' *Administrative Science Quarterly*, 23 (4), 1978.

Zuber-Skerritt, O., 'Action learning and action research: paradigm, praxis and programs.' In S. Samkaram, B. Dick, R. Passfield, & P. Swepson (eds). *Effective Change Management Using Action Research and Action Learning: Concepts, frameworks, processes and applications*. Southern Cross University Press: Lismore, Australia, 2001.