DESIGNING A DRIVER ENVIRONMENT FOR RIGID INFLATABLE BOATS USING A USER-CENTRED DESIGN APPROACH

Reference NO. IJME 792, DOI: 10.5750/ijme.v164iA2.792

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KEY DATES: Submitted: 08/03/22; Final acceptance: 05/10/22; Published: 30/11/22

SUMMARY

Herein, the importance of design methods for a company's competence in the commercial world and the importance of integrating design into the product development process in the initial stages are discussed. Notably, driver environments on current boats are not ergonomically designed. Hence, this study aimed at designing a new driver environment with improved ergonomics and user experience that is aesthetically compelling to the market. This study is based on a user-centred design approach, which implies that all team members participate throughout the product development process to create design value for users by crafting innovative solutions that satisfy their requirements. Consequently, a new console, seating unit, and hardtop design that consider the importance of ergonomics, user experience, and manufacturability are developed. These elements are not only integrated in a user-friendly manner but also provide improved maintainability and productibility.

NOMENCLATURE

CAD	Computer-aided design
CNC	Computer numerical control
HCD	Human centred design
HMS	Human–machine system
ICSID	International Council of Societies of Industrial Design
IDSA	Industrial Designers Society of America
IEA	International Ergonomics Association
MDF	Medium Density Fibreboard
NPD	New product development
RIB	Rigid inflatable boat
UCD	User-centred design
WDO	World Design Organization

1. INTRODUCTION

Rigid inflatable boats (RIBs) are lightweight watercrafts constructed with a rigid planar hull and flexible tube. They are stable, fast, and perform well (Figure 1). In the marine sector, RIBs are often designed by naval architects and marine engineers with a focus on their aesthetics and performance. However, little attention is paid to user experience and ergonomics. Compared with other vehicles such as cars and planes, RIBs do not provide the best user experience in terms of their performance and ergonomics. Therefore, an industrial designer must consider user goals, industry requirements, and manufacturer capabilities when designing new products. The International Organization for Standardization (ISO) defines user experience as 'a person's perceptions and responses that result from the use or anticipated use of a product, system, or service'. User experience can be initiated from the user's first reaction or from favourable/unfavourable impressions in the long term (Kraft, 2012). End users are users who use a product or service. Stakeholders are defined as all participants that are regarded as significant in a study from the perspective of the designer. Hence, the stakeholders include the users, as well as the company (RIBTECH) and laws/regulations. The classification of the stakeholders is depicted in a stakeholder map, which indicates their connection to the study. This classification is inspired by the 'audience' from 'The Field Guide to Human Centred Design (IDEO org., 2015)'. Although all systems feature the primary user in the centre, secondary users are included as well. This study focuses on RIBTECH's Northstar 910 RS model (Table 1), which was constructed in 2015 by a designer whose primary focus was style. Based on feedback from dealers, users, and production personnel, the model presented ergonomic, production, and aesthetic problems in addition to its superior performance, thus resulting in low sales. Considering the increasing influence of customers on the decision-making process in the design industry, their favourable perceptions and reactions regarding the use of a product are essential. Hence, RIBTECH decided to address these issues by redesigning the deck and other components of the model. Based on the problem and requirement analyses, benchmarks, and interviews conducted with users, engineers, workers, and managers, certain components such as the console, seating units, and hardtop must be changed.

The user environment for the Northstar 910 RS is extremely complicated and involves a long production process, as well as complex assembly details for the console. Hence, the process involved is time consuming, and the production manager and workers are likely to make mistakes. The seats, which are difficult to fabricate and are extremely large in size owing to the material used, are uncomfortable and hinder user movement during driving. The hardtop comprises fiberglass and stainless-steel sections that are extremely heavy; hence, vibrations occur at high speeds, thus deteriorating its performance. In addition, the console, seating units, and hardtop design are visually cluttered owing to their volumes and colours. Meanwhile, the investment cost for these three mouldings is less than that for the deck. Notably, these factors affect the aesthetics of a boat.

This study was conducted at the Izmir Institute of Technology in the period between the fall of 2017 and the spring of 2018. The primary objective of this study was to demonstrate the positive, long-term effect of the user-centred design (UCD) process practiced in the initial stages of new product development in the early areas of brand NPD. Hence, the user-centred NPD process was applied with the collaboration of managers, engineers, users, workers, and external suppliers at the beginning of the study to launch a boat.

In this study, the following questions were addressed based on the results of practice-led research:

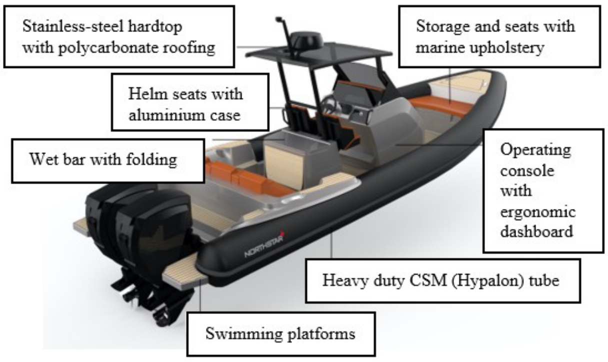

Figure 1. Main components of the RIB

Table 1: Technical data of Northstar 910 RS

Technical Characteristics	Value
Overall length	9.25 m
Overall beam length	3.06 m
Fuel capacity	500 L
Water tank capacity	80 L
Maximum engine power	600 HP
Shaft length	2XL to XXL
Light weight	1.900 kg
Maximum loading capacity	10 per 900 kg
Number of air chambers	6
Recommended tube pressure	0.22 bar/320 psi
CE design category*	B

*The CE Yacht Compliance Classification System is the European (CE stands for "Conformité Européenne" in French) dictating the standards for CE Certification for construction and sale of boats.

- How can UCD contribute to the development of better designed products?
- How does industrial design practice shape the NPD process in the workplace?
- What are the outcomes of applying the UCD approach in the initial stages of the NPD process?

A project was established for a case study to investigate the application of UCD in the NPD process by addressing the following questions.

For the console design:

- How can we improve physical and cognitive ergonomics?
- How can we improve user experience?
- How can we contribute to manufacturability?

For the seating unit design:

- How can we improve the physical ergonomics?
- Can we propose new materials and production techniques?
- How can we design more visually appealing seats?

For the hardtop design:

- Can we propose new material and assembly techniques?
- How can we design a visually and physically stable hardtop?
- How can we design a more visually appealing hardtop?

Three aspects that were consistent with the project goal were ergonomics, user experience, and manufacturability. Users typically drive boats at high speeds and in volatile seas. Therefore, ergonomics was a key element in the design process. The physical environment was the primary concern; however, other conditions such as wind, sun, waves, and salty seawater were considered as well. The interaction between the control panel on the dashboard and the layout of the console were addressed cognitively. Manufacturability characteristics were addressed based on the detailed design of tool-ready components, material selection, and the assembly of all components. By implementing the design methodology of Aneer and Hansols (2016), we performed the study by collaborating with users, engineers, marketing departments, and staff using the UCD approach. Evidence was acquired that highlighted the contribution of a design-led approach combined with the concept of 'value' extended to boat design through design knowledge. UCD approaches were implemented to investigate the feasibility of a design idea at an early stage via requirement and problem analyses based on interviews, observations, and benchmarks. Opinions obtained from clusters of individuals were used to develop user knowledge and suggest new elements for the design. The new boat concept combined new and existing components such as the deck and hull. Notably, design priorities in different professions are different, which applies to this study.

This study raises awareness regarding the necessity to create economic value in industrial design. In this regard, instead of identifying design as an 'add-on' or a temporary feature of a product, it is regarded as a value and a tool that facilitates competition and improves the performance of a company in the market.

Product design and development involves a series of steps or activities for preparing, designing, and commercialising a product. Ulrich and Eppinger (2016) mentioned that products can be developed appropriately via industrial design to satisfy the aesthetic and ergonomic requirements of users (Ulrich & Eppinger, 2016). Design practice is a cross-disciplinary approach and requires productive, analytical, creative thinking, and critical problem solving (Margolis & Pauwels, 2014). Its aim is to satisfy user expectations and create competitive products with distinctive characteristics (Hertenstein et al., 2005; Goffin & Micheli, 2010). Better designed products provide a competitive advantage and thus increases the success probability of companies (Goffin & Micheli, 2010). NPD supports firms and economic performance across market competitions and requires professional experience (Walsh et al., 1992). Design increases the competence of firms, thus resulting in an increase in export potential (Rothwell & Gardiner, 1984; Walsh et al., 1992; Bryson & Rusten, 2011). Meanwhile, industrial design supports the functional and technical features of products as well as their visual identity, thus enabling new product configurations (Crawford & Di Benedetto, 2008). During NPD, designers serve as an interpreter, a coordinator, and a facilitator, in addition to their original role (Turner, 2010). The role of the designer has transformed from a specialist in creating products to a leader (Perks et al., 2005), as well as from supporting efforts to developing new products (Turner, 2010). Europeans regard the user as a partner, which suggests an inclination towards a participatory approach. The two aspects above affect each other and were considered when developing the UCD (Sanders & Stappers, 2008). UCD is often used interchangeably with human centred Design (HCD). However, UCD is a more focused and concise version of HCD, with a broader analysis of the focus audience. UCD focuses on the users during the design process to satisfy their requirements and to create products with higher practical utility (Wilkinson et al., 2016; Abras et.al. 2004).

Designers should focus on users and tasks in the initial stages by conducting empirical measurements and implementing an iterative cycle (Gould & Clayton, 1985; Brown & Mulley, 1997). To apply UCD effectively during product development, one must obtain inputs from the users, designers, and stakeholders at each stage to understand the requirements more closely such that more appropriate products and services can be created (Lindgaard et al., 2006; Kujala, 2003; Muller, 2002). By implementing the participatory approach, these ideas and insights can be used to develop more accessible and usable products for a wider segment of the population (Etchell & Yelding, 2004).

Furthermore, the implementation of UCD within the product development process has been described as interdisciplinary, value adding, and accessible (Wilkinson et al., 2016); in the implementation, user requirements and behaviours are analysed, defined, and synthesised, as well as regularly translated into designed products or services via an iterative process (Mao et al., 2005). It is defined as value adding as it improves the design outcome by enhancing the user experience. Additionally, it yields greater economic output (Boztepe, 2007).

UCD methods based primarily on ISO 13407 (ISO/IEC 1999) have been proposed to guide the development of user-friendly products. The focus of those UCD methods is four fold: Understanding and specifying the context of use; specifying user and organisational requirements; creating designs and prototypes; and performing user-based assessments (Wilkinson et al., 2016).

In this study, the UCD approach was implemented as the basis for product development. To design a boat, a novel approach was used in addition to a classical process that is more suitable for boat design than previous processes. User experience can be triggered by the initial reaction, as well as created by favourable and non-favourable impressions experienced in the long term (Kraft, 2012). To improve user experience, designers must understand the difference among users' opinions, behaviours, and emotions, and identify the appropriate methods for each of them (Sanders, 2002). Norman (2013) claimed that addressing an action by experiencing a product instead of performing tasks yielded better user experience. Experiences, apart from their abstract form, are subjective, non-physical, and can be defined as the core value of a product (Cain, 2010). A limitation of this study was that the newly developed designs must be realised based on the company's capabilities, and that additional investments other those for the moulds were not allowed. Notably, RIBTECH requested a new console, seating units, and a hardtop for the NorthStar 910 RS, which was launched in late 2018. The new boat design will feature new components and existing ones such as the deck and hull.

2. DESIGN APPROACH

The study is based on a design that includes its role in professional practice, which was previously contextualised but not defined by history. Furthermore, the aim of the study is to reflect the practice based on the insider perspective of a designer who is positioned as a group member. This refers to a person who can understand the rules, expectations, and discourses of a community or culture. Practice-led research is a key component of the exploration and application processes. The findings of this study will be analysed via a thematic narrative approach to understand the manner by which industrial designers can contribute to NPD in a cross-disciplinary workplace. In design research, the research topic is primarily determined by the research specialists instead of the design practitioners The core of design research is to obtain the most recent information pertaining to the nature of practice, and it seeks answers to improvements instead of constructing and reflecting on new products (Candy, 2006).

The approach above provides useful knowledge generation outcomes that are based on both research and practice (Allpress et al., 2012). Practice-grounded analysis is a promising method that perceives information as a sensitive action; it provides a basis for inventive research as a predictor and an enabler of modification. Demand for research qualifications at the master's and doctorate level has increased in areas of exemplar art, architecture, and design practitioners such that professional leadership roles that bridge academia and industry can be filled (Allpress et al., 2012, p.1). The case study performed in this study focused on a design project undertaken in a corporate setting. In the case study, older and newer product designs were compared based on the NPD process in UCD. It highlighted the importance of applying UCD in the preliminary stages of NPD, which remains the main concern in design practice.

In the analysis phase of the study, qualitative data were acquired through fieldwork (Table 2). Qualitative analysis was performed as it was the best approach for small samples, although the results were neither measurable nor quantitative. However, it provided a complete description and analysis for a research subject without limiting the analysis scope and the response type of the participants (Collis & Hussey, 2003).

In the analysis above, the users and boats were first observed. Four field trips were conducted, and five users were observed while they were riding the boat. The designer was an active researcher on board the boat. Data were acquired by capturing photographs and videos using a GoPro camera. Unstructured interviews were conducted with the five users, two marine engineers, the production manager, the sales manager, three external dealers, the owner of the company, and four workers. The unstructured interviews resulted in a casual interview with unrestricted ideas. In addition, a telephone interview was conducted with the marketing manager. The unstructured interviews were conducted face-to-face to elicit the participant's emotions, feelings, and opinions regarding a selected object of analysis. The method used to obtain information was a semi-structured survey, which served as an interview guide. Specific questions were prepared to achieve the objectives via the interviews; however, additional questions were posed during the interviews. In addition, benchmarking was conducted via the Internet and based on six competitor boats in Bodrum Marina and the Istanbul Boat Show. Casual interviews were conducted with external retailers regarding the advantages and disadvantages of other brands.

Table 2: Qualitative data acquisition methods used in current study

Research Type	Research Method	Research Technique
Field Research	Observation	Examine photographs of boats and record videos on the boats while driving (as an active researcher)
		Examine the users on the boat (as a passive researcher)
	Unstructured Interview	Interview five users, two naval engineers, the production manager, the sales manager, three external dealers, the owner of the company, and four workers (semi-structured questionnaire)
	Phone Interview	Interview the marketing manager to understand RIBTECH's expectations
	Survey	Perform benchmarking via the web
		Perform benchmarking based on six competitors' boats in Bodrum Marina and the Istanbul Boat Show
		Discuss with external dealers regarding the advantages and disadvantages of other brands

Additionally, benchmarking was performed based on boat resellers, fishing tournaments, and tradeshows. The semi-structured interviews were conducted with users, managers, and mechanics to understand the state of boating and future trends. The interviews with the users were conducted on their boats and lasted approximately 30 min. The interviews with the managers were conducted in a production area on the boats; these interviews lasted approximately 20 min. Interviews with workers were conducted in their workshop and lasted approximately 10 min. To comprehend the vision of RIBTECH as the production company and Northstar as the brand, the phone interviews were conducted with personal from the marketing department based on a set of questions crafted in advance. The interviews lasted approximately 20 min. To obtain data regarding laws and regulations pertaining to the console design, an unstructured interview was performed with an engineer at RIBTECH, who was responsible for the CE marking of the products (see Appendices B and C).

2.1 IMPLEMENTATION OF CURRENT STUDY

Vrendenburg et al. (2002) outlined the overall UCD process in terms of four phases: analysis, design, evaluation, and implementation. The UCD approach for product development was used in this study, similarly as the four-phase model of Vredenburg et al.

- In the analysis phase, data that might be relevant to the design of new boat components were acquired.
- In the design phase, concepts were developed to improve the Northstar 910 RS. The concepts were based on ideas birthed from the analysis phase.
- In the evaluation phase, the designed components, i.e. the new console, seating units, and hardtop, were evaluated based on ergonomics, user experience, and manufacturability. If required, the designer would return to the previous phase or proceed to the next, since UCD involves an iterative cycle.
- In the implementation phase, the components were designed in three-dimensional (3D) models and physical prototypes.

The industrial designer participated in the production area of RIBTECH for all three aspects of the process—inspiration, ideation, and implementation. Meetings with RIBTECH's marine and production engineers and managers were arranged regularly throughout the study to obtain and provide feedback at all stages.

At the start of the project, a Gantt chart was created for scheduling purposes (Appendix A). The aim of this phase was to understand the study objective and business capacity, as well as to determine the manner by which the phases are to be arranged throughout the schedule. During the planning phase, brainstorming sessions were conducted to address critical points pertaining to the design of the new boat console, seating units, and hardtop.

2.2 ANALYSIS

To describe the problems and understand the requirements of the users and stakeholders of the Northstar 910 RS, methods such as benchmarking, interviews, observations, requirement analysis, and problem analysis were used. The results of the interviews and observations were recorded in the 'stakeholder profiles', which were the main output of the analysis phase. Similarly, problem and requirement analyses were conducted in the analysis phase.

Interview and video materials from field research were obtained by diversifying the design process through the inclusion of users, passengers, and multiple stakeholders. All components of the newly designed product were created by considering usability and design. Documenting the observations via video recording using GoPro cameras enabled the designer to reflect upon the data obtained from field trips and determine the details that were disregarded while performing experiments on the boat. Based on the data obtained and feedback from field research, UCD/HCD was utilised in the design process. Specifically, UCD/HCD was used to

- Understand and specify the use context.
- Specify user and organisational requirements.
- Create designs and prototypes.
- Conduct user-based assessments.

The use of UCD and field data was crucial in the design process, considering the ex-ante and ex-post evolution cycle of the prototype. The following aspects were considered or implemented:

- All components should be easily accessible for maintenance, either from the inside of the console or via a service hatch. The style of the hardtop was modern, i.e. it featured clean lines and textured powder-coated paint. The assembly of the hardtop allowed easy installation and maintenance by the workers.
- The layout for the electronics and gas throttle for the boat should be simple and ergonomic. Control components for the boat driving process were placed on a linear surface in front of the driver's seat, which ensured that the controls were within reach, good visibility, and a comfort zone for all drivers. The steering wheel and throttle were positioned at the correct angle in front of the user.
- The seats exhibited distinct levels of exclusiveness. However, a functional and ergonomic seat was the most fundamental aspect. The new driver environment was designed to be applicable to a wide range of users worldwide. Dashboard and seats were adjustable to accommodate most users and provide an ergonomic driving environment for drivers of different sizes. The new placements of the console, seats, and hardtop provided ample room for the driver and passenger without compromising their comfort, reach for control, and safety.
- Power outputs and USB ports were installed in the storage box in front of the passenger seat, with USB and AUX outputs available for charging mobile phones and playing music.
- The colour options for the boat were considered.
- We selected black for the boat to achieve a more aggressive and sporty appearance, while ensuring practicality and durability. The exterior of the previous console featured grey and white colours.
- Drink/cup holders were implemented.
- Tool storage was considered.
- Storage for documents and instructions were considered.
- The front storage boxes provided space for additional equipment such as tools or other objects. A simple object such as drink holders improved the comfort of the driver and passenger.

2.3 REQUIREMENT ANALYSIS

A requirement analysis was performed to understand the requirements and expectations of different users and stakeholders involved in this study (Table 3).

Table 3: Requirement analysis: requirements identified from users and team members

User Requirements	Able to sit and stand comfortably while driving Able to reach and control all instruments Good vision Storage for equipment An aesthetically attractive boat Feeling of safety Feeling of being in control Feeling of being independent Feeling of satisfaction with work
RIBTECH Requirements	A competitive, upgraded, and attractive product A profitable product A modern design achievable using current manufacturing technique High quality satisfying customer expectation Possibilities for additional opportunities
Manufacturer Requirements	A design achievable by current manufacturing capabilities Comprehensive documentation regarding design options Comprehensive documentation for future implementations (CAD and drawings)
Manager Requirements	Affordable yet high-quality products Functional boats with minimal unexpected maintenance Desirable ergonomics, safety, and vibration Products are customisable to specific requirements A boat that can accommodate different users
Service Mechanic Requirements	Easy maintenance of components Comprehensive documentation of spare components Prompt delivery of spare components Ergonomic access to service points Sufficient information regarding boat status and necessity for service Possibility for installing additional devices practically
External Seller Requirements	Possibility of customisation and additional options for customers Knowledge regarding customer (buyer) requirements Good customer relationships
Laws and Regulations	In the global market, the product must comply with all applicable laws and regulations

The requirement analysis primarily focused on the expectations of the users and stakeholders from the innovative design, in addition to their overall expectation from the study. The manufacturers required a comprehensive documentation of the findings and design decisions to manufacture the new boat and introduce to the market. By contrast, the users were not interested in the process by which the new boat was manufactured, although they specifically demanded a better performing product.

2.4 PROBLEM ANALYSIS AND DESIGN OPTIONS

The problem analysis is a complement to the requirement analysis. The problem analysis performed in this study focused on the focused on problems highlighted in the existing boat design (Figure 2).

The problems were identified based on comments from the interviews; however, additional details were also obtained by observing the users while they were driving the boat.

The final step of the design process was to develop a complete concept for the new console, seating unit, and hardtop.

VIEW The users complained about the view angle during driving. The area above the dashboard was placed high and obstructed the view.
GRIP No grip area or handle was available for people standing near the driver. At high speeds, safety was an issue for the passengers.
STORAGE No space was available to store loose items such as mobile phones, keys, covers of electronic equipment, caps, and sunglasses.
RESTRICTED MOVEMENTS The users complained about the design of the seats, which restricted their arm movements.
PRODUCTION Personnel from the production department complained about the production process of the seats, which required two-sided moulds and was time consuming.
ASSEMBLY The hardtop was assembled at the outer side of the console, which rendered the width of the walking path narrower.
WEIGHT AND VIBRATION The hardtop was composed of fiberglass and stainless-steel profiles, which were extremely heavy and thus deteriorated performance and vibration at high speeds.
VISUALLY CLUTTERED The console, seating units, and hardtop design were visually cluttered owing to their volumes and colours.

Figure 2. Problem analysis

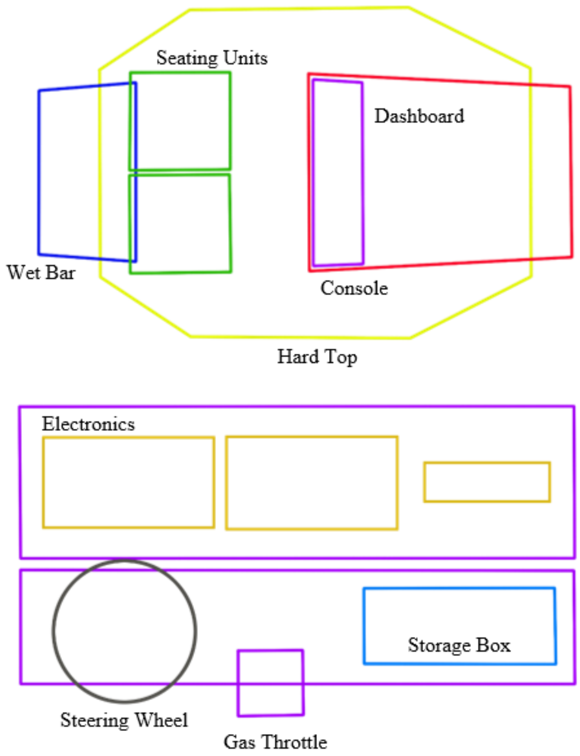

Figure 3. Component mapping of driver environment and dashboard

2.5 DESIGN

The ordering method was component mapping, and the exploratory methods were early sketching, problem solving, and visual collages used to inspire and develop ideas during the design process (Figure 3). The final innovative techniques were co-creation and mind sketching. Users and stakeholders participated in the co-creation. The processes implemented in the phase were repeated, and the organisational documents were clarified repeatedly throughout the process.

3. EVALUATION AND IMPLEMENTATION

A final design was selected. Subsequently, it was modelled completely and milled via computer numerical control (CNC) using a medium density fibreboard (MDF) (IZMOD). All the processes performed in this phase were conducted by the team at the RIBTECH workshop and that at the IZMOD workshop in Izmir. The development and construction of the prototype was conducted in close collaboration with the marine engineers and production staff at RIBTECH.

3.1 CAD MODELLING

All CAD modelling was performed in Rhinoceros 5.0. The development of the final concept began with the examination of the shapes and layout of the boat via a rapid modelling of surface models. A manikin named iMan was used, which was based on the Military Handbook, Anthropometry of U.S. Military Personnel (1991). The physical dimensions of the manikin were compared with the 5th to the 95th percentile from ISO 15536-1:2005 and assessed to provide a useful demonstration of these measurements for a visual assessment of the boat layout and size. The manikin was used as a basis for the dimensions of the console, seating unit, and hardtop. Results of the CAD modelling and experiments show that if straight and curved lines with sharp edges can be created, a sleeker design can be achieved. To accommodate the supplier who would manufacture the hardtop, the production personnel was asked if laser cutting the stainless-steel sheet and welding it to other profiles were possible (Figures 4 and 5). According to the production personnel, the hardtop can be manufactured via the above methods; thus, the design was modified to accommodate the manufacturing possibility.

Subsequently, the design was further developed, and drawings were created for all the components to be manufactured. The components, such as the steering wheel, electronic devices, stainless-steel components, upholstery boxes, and storage compartments were ordered from manufacturers such that the final prototype would appear realistic. After discussing with the stakeholders, most of the designs were realised using moulded fiberglass and laser-cut bent stainless-steel sheets. All detailed design drawings were supplied in a digital format to RIBTECH and are omitted herein.

Figure 4. CAD modelling of Northstar Orion 9

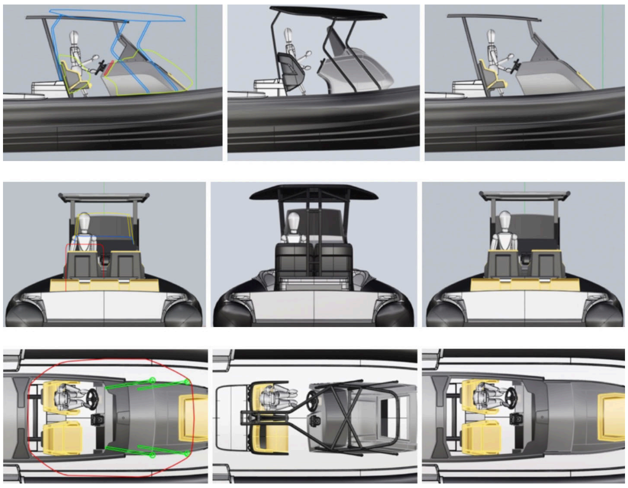

Figure 5. Front/top views and juxtapositions of Northstar Orion 9

4. MANUFACTURING OF PROTOTYPE

Discussions were conducted with the production staff to fine-tune the assembly details of the components and to examine the possibilities of processing fiberglass, stainless steel, and glass. The production methods used were CNC milling and laser etching. The designer alternated between sitting at the computer to design components and being present on the production line to construct the prototype during the final phase of the study, which is an iterative period. Subcontractors assisted in the fabrication of the stainless-steel components for the seat units and hardtop (Figure 6). Drawings were continually delivered to the production staff, and components were fabricated as the prototype was developed. Construction began with the assembly of the console and seats with the hardtop, and the prototype gradually filled the deck of the boat thereafter. Numerous design decisions were made during production while the prototype was being completed.

Figure 6. Northstar Orion 9 Console, console glass, seat, hardtop prototype, and final product

4.1 FINAL CONSOLE DESIGN

The console was defined as two sections, i.e. the dashboard and interior. The dashboard was designed such that it is easy to access and can be changed and customised when required. The dashboard featured flat surfaces that rendered it easily customisable to accommodate customer requirements. The surfaces can be drilled with holes to accommodate new tools; hence, the console need not be customised. The average life of a boat is approximately 10 years, within which the customer's requirements would change. RIBTECH implements custom finishes to provide their customers with updated consoles that enhance their boating experience over time. Furthermore, RIBTECH performs a comparison between the previous and current console designs to gain perspective regarding the overall design change afforded by this study.

The new console with a wide front window provided better visibility. The darker colour implemented on the boat provided a more aggressive and sporty appearance while affording functionality and durability. The exterior of the previous console featured grey and white colours. The design of the dashboard was considered well and featured a customisable layout for a chart plotter, an engine gauge, and electrical switches. In addition, a storage box was installed in front of the passenger seat with USB and AUX outlets affixed to it, which is ideal for charging cell phones and playing music. To ensure the passenger's safety during driving, a handle was installed to the right of the passenger seat. A decorative acrylic component laminated with carbon-fibre foil highlighted the design of the dashboard and provided an area for the electronics.

4.2 FINAL SEATING UNIT DESIGN

The seating area was defined as two sections, i.e. the seat section, and the assembly section between the seats and wet bar. The primary goal of the seating assembly design was comfort during use and allowance for arm movement.

Figure 7. Northstar Orion 9 with redesigned back seats, electronic control switches, and console carbon-fibre film laminated plexiglass

Additionally, the production process for the seats was simplified, i.e. curved, laser-cut stainless steel was used instead of a double-sided mould. The upholstery of the seats was replaced with a more sophisticated textured and patterned fabric, which provided an elegant appearance. Handles were installed on the mounting portion of the seat unit to provide safety when walking or when standing while driving.

4.3 FINAL HARDTOP DESIGN

The hardtop was defined as two sections: one section with welded laser-cut stainless steel and another with welded dark-coloured plexiglas panels for shading. The primary goal of the hardtop design was to reduce the weight via a more stable construction that affects the boat's performance at high speeds. In addition, the production process of the hardtop was simplified from double-sided moulding to welding laser-cut stainless steel.

The design of the hardtop was spacious and well-lit owing to the use of plexiglas panels. The hardtop was mounted on the console, which allows a wide walkway. The style of the hardtop was contemporary, with clean lines and textured powder coat finish. The mounting of the hardtop was considered in the design and allows for easy installation and maintenance by workers.

4.4 ERGONOMICS

By implementing physical ergonomics via the development of new products and services, the occurrence of injuries such as musculoskeletal disorder can be reduced (Silverstein and Clark, 2004). Therefore, the user's body measurements, defined as the anthropometrics, must be considered. Anthropometrics involve the design for all and the design for the average. Design for all implies that the parameters in the design process are adjustable, thus ensuring good ergonomics for 'all' users. The design for the average involves using the average human anthropometrics. Examining the anthropometrics in the design was vital to ensure good ergonomics for the user. The user population, which included men and women, showed different anthropometrics. Adjusting the design appropriately allows the design to accommodate most users. The anthropometrics for the 5th to 95th percentile of the operators was implemented for the design of the driver environment in the case study, and measurements from previous boat designs were used to ensure physical comfort.

The prototype boat had successfully completed a series of tests and performance evaluations, and its various features have been implemented. Additionally, RIBTECH reviewed the design and layout with the customers, mechanics, and engineers. The physical boat allowed the customers to appreciate the concept as well as provide feedback. The first boat served as a sales item for potential customers. The wide windows of the boat provided a large field of vision for the driver and passenger. The folding seats allowed for comfortable driving while the driver is standing or sitting. A dark coloured, transparent hardtop provided a spacious and well-lit feel. The new placements of the console, seats, and hardtop provided sufficient space for the driver and passenger without compromising their comfort, reach of control, and safety. The front storage bins provided space for additional equipment such as tools and objects. Simple elements such as cup holders added to the comfort of the rider and allowed the passenger to bring water while riding the boat.

Boating control components were placed on a linear surface in front of the driver's seat. This ensured that the controls and comfort zone were within easy reach for all drivers. The steering wheel and throttle were positioned at the correct angle in front of the user. A dashboard was installed in front of the driver's seat. In this area, controls such as the chart plotter, engine display, stereo, and electrical panel were easily accessible and visible to both the driver and passenger. The dashboard components were removable with screws to allow quick access and repair, and to provide ergonomic operating conditions for service mechanics. A storage box was installed in front of the passenger area to allow customers to store their mobile phones, keys, and other items.

5. RESULTS

In this study, a UCD that satisfied the requirements and preferences of users and stakeholders was realised. The industrial designer, who possessed structural and technical expertise, was the link between the company and its clients.

The first step of the design process was to consider the current problems prior to proposing a new idea (Cain, 2010; Norman, 2013). RIBTECH demanded a new and more visually pleasing boat to replace the previous boat, which appeared outdated. The final boat designed in this study was not only sleek and appealing but also satisfied the requirements of consumers and stakeholders. In addition, ergonomics and usability were introduced to the new boat. Usability measures the ability of a specific user in a specific context in using a product design to achieve a defined goal effectively, efficiently, and satisfactorily. The industrial designers and engineers at RIBTECH analysed the design usability of the proposed boat throughout the development process iteratively. Context exploration was performed in the study, which ensured that current issues were identified, thus allowing designs to be decided based on them.

Creating a more physically and cognitively ergonomic driver environment would provide better to both users and manufacturing personnel. In fact, a well-designed driver environment is not only the selling point owing to the appealing appearance, but can also provide a better economic outcome. UCD not only focuses on the physicality of a product but also the user requirement. RIBTECH attempted to understand their customers more closely based on the stakeholder profiles. Capturing the awareness, feelings, and perceptions of customers would allow RIBTECH to develop more effective products.

From an industrial design practise perspective, this study shows that UCD methods can be strategically implemented in a conservative industry even by non-experts. Managing a product development process requires a clear understanding of the methods, goals, and the context in which the process occurs. Similarly, the technique adopted must be customised to the context to achieve successful outcomes, and industrial designers are constantly developing their skills to perform such customisations. The prototype developed in this study allows RIBTECH and the customers to view the new boat components. In fact, the physical model allows the concept to be understood without necessitating technical expertise or the ability to interpret a 2D drawing or 3D model. Furthermore, the visual presentations were useful as a communication tool between people with diverse backgrounds, as reported by Nilsson et al. (2015).

6. CONCLUSION

In this study, UCD and NPD processes were performed, which allowed the realisation of product design with improved ergonomics, user experience, and manufacturability. The UCD approach was adopted to support user involvement, thus allowing promising projects to be transformed via the product development process. In a UCD, the user requirement is superior to marketing considerations. Based on a literature review, the co-production of value presents more potential for establishing stronger bonds between products and users. Additionally, based on insights gained regarding the role of the designer in UCD, we focused on the involvement of users and stakeholders in the design process, which offered a more satisfying approach for product development.

In the case study, some components of the RIB, Northstar 910 RS were redesigned in terms of ergonomics, user experience, and manufacturability. The new screen, seat unit, and hardtop of the Northstar 910 RS were designed to be more ergonomic to improve the user experience, facilitate manufacturing, and render the boat more aesthetically pleasing. The combination of NPD with UCD was utilised in the case study to satisfy the user requirements and to encourage their involvement towards the solution. Based on interviews and observations, the problems, requirements, and design opportunities were identified; subsequently, the product was redesigned based on the existing co-created values.

Furthermore, as a designer, we attempted to improve the user experience by focusing more on the ergonomics. Inputs from other stakeholders related to the boat such as the production engineers, workers, service mechanics, and external vendors were considered in the process. The goal was to create a new concept on behalf of the client that would render the product competitive in the global market. Ergonomically, the design of the console, seat unit, and hardtop was a compelling selling point, and the improved aesthetics would improve the position of RIBTECH among its competitors.

The design was modelled in a CAD model; subsequently, the model was fabricated via CNC milling and moulding. In addition to understanding the opinions of RIBTECH, users, and other stakeholders regarding the proposed concepts, we created a prototype and devised modelling techniques to support the co-creation of value. The rough prototype allowed the new console to be physically tested in a manner not possible using a computer model to satisfy the ergonomic requirements of the drivers. Meanwhile, the model CAD can serve as a basis for the development of future boats to establish the brand name for 8M, 10M, and 12M RIB. In other words, the methods and tools used in the case study are applicable to various product development processes.

All the possible strategies that designers can propose to support user-centred development was not considered in this study. However, through this study, the designer was able to use some design tools and methods that were not used in RIBTECH's previous design projects. Working on a project where a prototype is immediately fabricated allows the feasibility and acceptability of the strategies mentioned earlier to be evaluated—the strategies are based on the different roles of designers for supporting the user experience, instead of product or technology changes. This practical experience only addressed some problems in redefining the role of designers and those pertaining to tools for supporting UCD. Nevertheless, this study provided an excellent opportunity to develop various products and collaborate with different teams, which involved theoretical considerations and concrete problem-solving activities pertaining to UCD.

The novelty of this study is that UCD tools were used in the NPD process to address specified research questions posed to the manufacturer. The information obtained through interviews, which was composed of information pertaining to specific products, was relevant to the boat users, manufacturers, and sellers Thus, the boat components were redesigned based on the requirements by RIBTECH. Another novelty of this study is the work structure. Although not pre-defined in this study, subthemes (e.g. user experience, ergonomics, and co-creation) became evident during the identification for the most appropriate approaches. The work in this study was developed by identifying alternatives, developing ideas, evaluating them, and redefining the conditions for a specific domain.

The results obtained can be categorised as tangible and intangible benefits. The tangible benefits were quantitative activities resulting from the application of UCD in NPD, including improvements in the ergonomic driver environment, a more aesthetically pleasing product, improvements in the production process, better use of materials, and the creation of a brand identity afforded by product designs. The intangible benefits of the project were qualitative benefits, which were not easy to evaluate. Specifically, the intangible benefits were long-term assets such as the intellectual property of an organisation. Intangible benefits can increase organisational transparency and responsibility, allow more time for data access, as well as increase customer satisfaction and market value.

The actual objectives of the project were based on these intangible outcomes. Specifically, the intangible outcomes in the redesign of the driver environment for the RIB with focus on UCD were the development of a connection among users, stakeholders, and product; increased awareness regarding the importance of applying UCD in the initial stages of NPD; and the ability to perceive products from a design perspective.

The study showed that companies can benefit from collaborating with users and stakeholders in the design process, i.e. their products can be perceived from a unique perspective and a stronger connection can be achieved between team members of different disciplines. The users and stakeholders successfully identified the user requirements owing to their collaboration. In terms of the overall benefits and outcomes of this study, one may conclude that the case study project had achieved its primary objective of demonstrating the positive, long-term benefits of adopting UCD in the initial stages of NPD process. The Northstar 910 RS redesign project has contributed positively to RIBTECH, and other design projects are currently in progress.

7. ACKNOWLEDGEMENTS

We would like to thank the professionals who were associated in the project of the case study for this research at RIBTECH: President Cengiz ARSAY, the factory manager Murat KAYA, and the experienced naval engineer Burak GÜRSES. Without their participation and experience, the project could not have been successfully conducted.

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