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# *Surfboard Industry Forecast*

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## Abstract

## 1. Introduction

Surfboard design has always been a very personal thing. Shapers tend to be surfers themselves, and board design is as much an engineering feat as it is a love for surfing. Professional surfers work closely with shapers, as each surfer rides waves differently, and they know better than anyone how their surfboard needs to perform. The design process of a surfboard has always been a case of trial and error. A template is designed, and then experimented with in the water, then feedback is considered and alterations are made accordingly [1].

From surfboards carved from trees, weighing 100 pounds, and having the maneuverability of a log, the history of the surfboard has shown a great evolution in surfboard design and manufacturing [2].

There are many theories behind the practice of surfboard design. The surfboard has seen multiple generations of design enhancements since the movement started gathering momentum in the 1950's. However, new innovation peaked in the 1960's and continues to evolve at a much slower pace. In fact, the industry has seen the return of balsa wood, long boards, and traditional shapes – a retro revival of sorts. The design of a surfboard still remains a fusion of ideas and instincts shared by the surfer and his or her shaper [3].

The surfboard design process begins with identifying the desires, needs, or goals of the surfer and his/her environment; identifying the variables (dimensions, rockers, bottom contours, deck contours, foils, templates, rails, fins, and more) in a specific technology (surfboard shaping and construction); hypothesizing arrangements of these variables (6' 2" x 18 1/2" x 2 3/8", squash single to double concave, soft crown deck, moderate foil, soft thin round rail) through intuition and reasoning; testing the results of these arrangements (surfing and observation); and bringing new hypothesis into the process based on these tests and any new ideas that may develop. Surfboards may be grouped into several primary classes: Short boards, Specialty Short boards, Big Wave Guns, Hybrids, and Long boards [3].

This paper will explore the history and evolution of the surfboard, the composition and primary decision elements used in surfboard design, the major technology enhancements and branches of evolution, and provide a foundation that can be used to predict future technological enhancements in the surfboard industry.

## 1.1 Surfboard History

**THE HISTORY OF THE BOARD PRE-50's**

Surfboards have a long and colorful history. Their roots can be traced back to the Polynesian Islands in the 6th century. Surfing as we know it (standing on the board) migrated to the Hawaiian Islands where it became very popular during the mid 18th century. It was originally a sport reserved for royalty. The boards were made out of solid would and could be more than 150 pounds – granulated coral was used as sand paper and glossy nut oil was used to waterproof the wood boards [4].

The sport was introduced to the United States in 1865 when two Hawaiian Princes came to study in the United States. It's safe to say that the waves in Southern California were a little less crowded back then. A similar story can be found around the introduction of the surfboard to the United Kingdom 1890 by two Hawaiian Princes. The surfboard really took root in Australia, when Duke Kahanamoku, the Hawaiian born Olympian, demonstrated the sport on one of his visits in the early 1900's. From this point on there was no turning back and the surfboard continued to gain in popularity around the globe.

As the sport gained in popularity the surfboard began to evolve in form and function as well. It evolved from a solid 10 foot long redwood plank which acted like a sponge when in the water for extended periods (1920's); to a hollow core board that was both lighter and longer (up to 16 feet long) still made out of wood. These latter boards were called a "Cigar Box".

The next revolution was the introduction of balsa wood as a material for surfboards. Balsa wood is a hardwood that grows naturally in places like South America. Its water content can be as much as 90%, and when cured correctly, is strong, light, and easily shaped. The balsa wood surfboard dominated the surf industry in the 1940's and late into the 1950's.

**SURFBOARDS OF LATE 1950's & 1960's**

Southern California has always been one important focal point for surfing (along with Hawaii and Australia) and it is also an important center for the aerospace industry. As Engineers, that were also surfers, experimented with new materials, the polyurethane foam board (covered with fiberglass) emerged as the dominant design in the industry. The advantage of foam was that it removed excess weight and allowed shapers to produce boards that were shorter in length and easier to turn. This was ideal for doing turns and tricks on even smaller waves. It also aided the industry by making surfboards easier to shape, hence faster to produce and market [4].

During the 1960's the design of surfboard continued to evolve to meet the increasing demand for performance, speed, and big wave surfing [2]. Although long boards were still in the market, and were in demand, wood languished in popularity and was mostly supplanted by foam and fiberglass surfboards. The “short” board became more popular in this period hovering around the 6 foot mark. The shorter surfboard of the 1960’s was faster and allowed for far more radical surfing maneuvers [4].

**THE 70's & 80's**

Improvements made to the surfboard during the 70's were few, with the exception of general experimentation related to rail curve (the bottom contour of the surfboard from tip to tail) and the shape of the nose and tail.

Another achievement was the introduction of tri fins which were two attachable "stick on" fins made of plastic that could be mounted in various positions outside of the original center fin that was permanently glassed on. This was a nice addition for several reasons; first it added greater stability to the rear of the board by enabling greater rail control in the water, and second gave the rider the chance to experiment with different fin arrangements without building a whole new surfboard. The fins were also easily replaced if it broke or fell off, and economically, the surfer didn't have to buy more than one board.

The early eighties were also a quiet time in surfboard design, although near the end of the decade, shaper's designs started to focus on certain areas of the board individually. In the meantime, the long board was entering a revival phase, which expanded into the 90's where it remains influential to the board design industry today. In fact, half of today's surfing population ride the same style of long board as the boards designed almost fifty years ago [4].

**THE 90's**

During the 90’s shapers could mass produce even lighter and thinner surfboards with the help of computer technology, allowing for far more radical movements on the waves. Another achievement of the 1990′s were the fish surfboards which featured a wider outline for extra stability and a v-shape cut out of the tail, allowing for more movement. Surfboards with 4 fins, known as quads, also hit the market with surfers having a wider range of shapes and templates for every type of surf condition [2].

## 1.3 Current Developments

The surfing industry is currently dominated by a few large enterprises (Quicksilver, Billabong, Hurley, Volcom, …) and many smaller companies. While the larger providers have moved to using automated tools to build boards in other countries like China with access to cheaper manufacturing, a great deal of surfboard production is still performed as a cottage industry by shapers who experiment with different shapes and materials. In terms of recent innovations, providers are still experimenting with different shapes and fin counts/placements. Several vendors have emerged that are working carbon fiber into the design of the board (for strength and flexibility).

Hydroflex Surfboards recently announced the Supercharger which allows the surfer to fill an air blatter to increase the stiffness of the board. This allows for more control over the ride and avoids having to have multiple boards for multiple conditions. Market interest has also grown rapidly for stand-up paddle boards. These boards are slightly larger than surfboards and allow the rider to paddle in any body of water without the need for waves.

Finally, the industry has also embraced additional concern for the environment. In fact, the Surf Industry Manufacturers Association (SIMA) officially endorsed the ECOBOARD Project in February 2013 to promote sustainable surf products. This has also led to a renewed interest in offerings such as balsa wood surfboards that are manufactured using sustainable materials.

## 1.3 Market Opportunity

Yāna Surf (www.yanasurf.com) is a new company based in Portland, Oregon that makes eco-friendly surfboard from sustainable balsa wood. Balsa is a hardwood that grows naturally in places like Ecuador. It is 90% water so when it is cured correctly it produces a buoyant, light, and very strong hardwood. In addition, it grows very fast; in many places it is even considered a nuisance. However, when shaped in the hands of a master, it produces an outstanding product that highlights the natural beauty of the wood and surfs extremely well (even smoother when the water is choppy). Since this natural material comes from the earth it brings a certain spirit with it as well. Since Yāna is focused on sustainability; a portion of all profits will be donated to planet friendly causes. The goal of Yāna Surf is to save the planet one beach at a time.

Yāna will produce two types of surfboards. First, the company will offer surfboards that are celebrity inspired. The celebrity for each board will be part of the project team for the board. They will help design and promote the board. In return, Yāna will donate a portion of the sales for the surfboard to the eco-friendly charity of their choice. Second, the company will offer a selection of Yāna designed boards that can be customized through the website. The surfer will be able to see their custom board created all the way from the mill directly to their doorstep. In addition, Yāna Surf will explore new technologies and communication tools to make the best product available and give an unmatched buying experience.

## 1.4 Project Objective

In preparation for launch the company needs to understand the current structure of the industry, the current state of the art, and the technology trends that exist in the industry. Yāna Surf has enlisted the help of ETM 632 students to map out the industry and provide tools that can be used to forecast technological evolution in the surf industry.

## 2. Surfboard Components

The modern surfboard consists of 8 elements which are the tail, nose, rocker, rails, fins, bottom counter, foil, and deck. See figure 1. The length of the board, the thickness of the board, and whether it is solid core or hollow core are also important considerations.

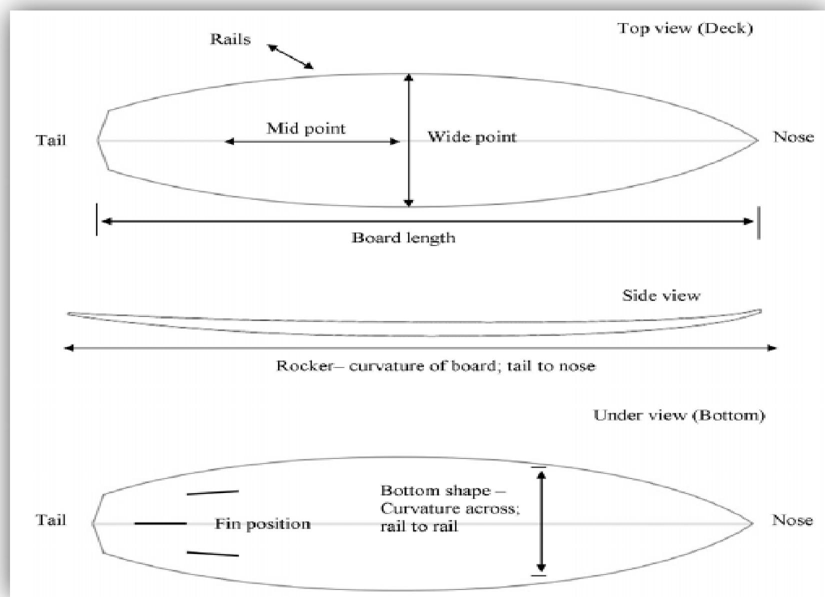


Figure1. Components of a Surfboard

**Tail**: The end of the surfboard which helps to hold and release water on the outside of a wave. Appendix A shows common types of tail shapes.

**Nose**: The front or tip of a surfboard. It helps cut through the water when a surfer drops into a wave. See appendix A form common shapes of tips..

**Rocker**: This is the bottom curve of a surfboard that helps to fit the surface of a board to the curve of a wave. Shapers often refer to a tail and nose rocker. Tail rocker is designed to have more curve at the end of the board in order to facilitate turning. Nose rocker helps the surfer to avoid dropping from the board while surfing into bumpy waves [5].

**Rail**: This component consists of the outside edges of the board from tip to tail. The Rails impact rotational flexibility, velocity, and planning. See appendix A for more detail [6].

**Fin(s)**: Fins add stability and give the surfer more control over the board. The number of fins can vary depending on the application. Single fins often are longer and bigger than other fins and are used for long board. Double fins are usually located close to the rail. They increase the speed and facilitate rotation.

Thruster fins are a fin set-up consisting of three identical fins. Two fins are closer to rails and the center fin is closer to the tail. A 2+1 configuration is the same as a thruster set up but the center fin is larger than the others - the larger fin is usually removable. This set up is most valuable when surfing smaller waves.

A “quad” setup is composed by four fins with two fins at each side closer to tails. The front two fins are larger. A “twinzer” setup is the same as thruster positions but four fins are installed and the front fins are smaller. A “bonzer” setup consists of 3-5 fins introduced in 1970’s [5].

Surfers and shapers continue to experiment with different numbers of fins, placement, size, shape, and materials. The ideal setup will often change depending on the type of wave, the shape of the board, the skill level of the surfers, and the type of ride the surfer is seeking.

**Bottom Contour**: This component plays a role in rotation and controls the speed of a ride. The convex shape lets the surfer ride the board with a lower speed and have move smoothly while concave increase the speed and provides a more maneuverable ride [5]. The bottom can also have a flat, channel (to help direct water flow), or vee shape.

**Foil**: it is the density of surfboard material from tail to nose in order to make some parts heavier or lighter compared to other parts depending on usage scenario for the board. Nose thickness is good for quick turning. Middle thickness depends on a surfer’s weights if the surfer is too heavy and the board is not thick enough he or she will sink; on the other hand, if the board is too heavy it is difficult for the surfer to control it. Tail thickness helps the surfer to paddle better [5].

**Deck**: it is the top surface of the board. Typical design choices include: domed, flat, or step.

Figure2 illustrates the alternatives of each factors and the associated innovation for each component. The application of these innovations will be discussed later in the paper. See appendix A [5].

# 3. Methodology

## 3.1 Technology structure

Surfboards performance can be tuned to maximize speed, maneuverability, or buoyancy. These characteristics play into the ability of a surfboard to work well under different conditions: big waves, small waves, moderate waves [5]. These can also be influenced different surfing styles. For example, a bigger surfer (larger mass) or less skilled surfer may need more floatation (buoyancy) to paddle into a wave. Surfboards that embody these characteristics are designed by selecting from different styles of the fundamental elements outlined if Figure 2 (below).

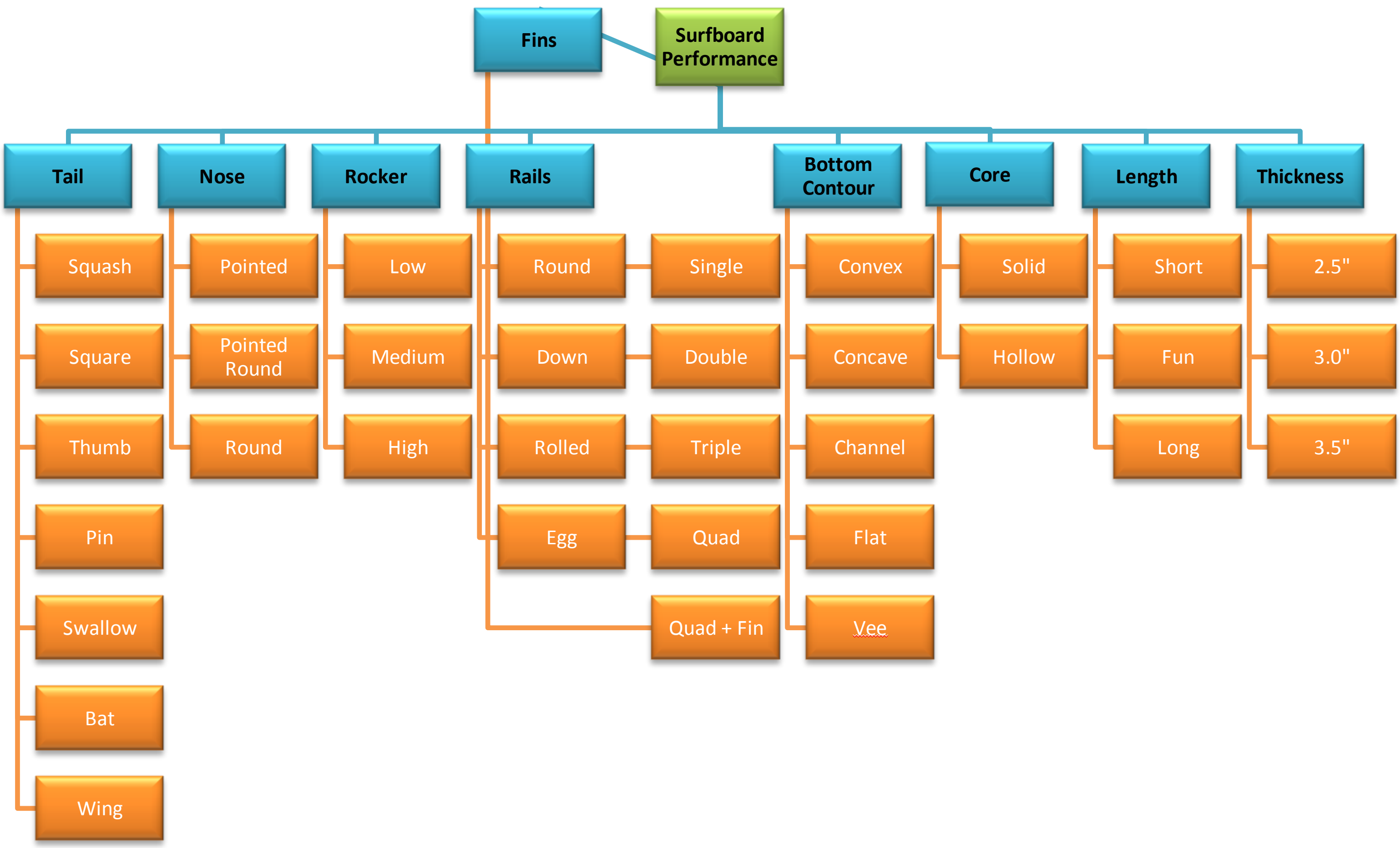


Figure2. Surfboard Technology Structure

## 3.2 Analyzing Historical and Innovative Trends

Once the technology structure was established, a trend analysis was conducted to determine the scope and timing of innovations. This would allow the nature of innovation within the surfboard industry to be established and narrowed to the most likely innovation areas. Utilizing a review of history, literature and existing industry briefs, the technology "space-time" (what, where, when) of the most prominent surfboard innovations were ordered (Appendix B).

From this, a qualitative technology lifecycle analysis was conducted based on historical indicators rather than patents since the surf industry has traditionally been driven by performance desires and hand crafted modifications wherein trial and error and feature combinations dominate. A quantitative, patent-based bibliometric analysis might provide more exacting results, but for the purposes of narrowing down historical innovations, this qualitative approach sufficed. Furthermore, as each technology could only roughly be placed within a decade's precision of introduction, this supported the use of historical indicators to gain an understanding of the technology "space-time".

Examining the "space-time", the peak of innovation in the surf industry occurred approximately in the late 1960's when new polymer materials allowed surfboards to maintain buoyancy while being shortened. This opened up a breadth of surf capabilities that were not achievable with the long board styles that had previously dominated. This "short board revolution" serves as the basis for the primary areas of innovation as they exist today. Legacy preferences continue to exist as well (continuation of previous styles, long board use, etc.), serving preferential splinter markets that utilize exclusive styles as well as providing any single surfer with multiple angles with which to address various wave conditions.

Considering this fact, the assessment of the "space-time" showed that while the "short board revolution" opened into multiple innovation areas, no one innovation is generational. One style does not usurp another; rather, an innovation might open up a new capability or surf style that expands the addressable market to include heretofore un-surfable waves or areas.

Examining the introduction years of the innovations on the "space-time" analysis, the average rate of innovation can be seen as being decreasing since the 1960's. There has been no major substitute of technique, design or material since the short board revolution. Despite being a slower innovation environment, innovation does continue to occur primarily in certain areas of design and material. Furthermore, new innovations exist in parallel with previous innovations rather than making obsolete older innovations in a generational fashion. The continuance of older innovations in parallel to new innovations shows that while the pace has decreased since the short board revolution, it's no less fertile.

Addressing the areas of innovations, two primary divisions were seen: Material and Design. Assessing each separately yielded two specific innovation branching schemes (Figure 3).

Prior to 1967, the materials utilized were generational as the sport of surfing moved from obscurity into popular knowledge [1]. Each innovation provided a marked advantage over the previous generation (e.g. lighter construction, increased buoyancy, increased durability). The introduction of easily shapeable, buoyant and lightweight materials (polyurethane, epoxy resin, foam) brought about the divergence of various material uses. The polymer and foam use persists throughout the industry and is currently the dominant form of construction [1].

With that said, some board designs have begun to incorporate carbon fiber into the designs being lighter and more durable than previous polymer use [8]. Balsa use has also re-emerged into prevalence as environmentally conscious designs have begun to gain popularity [1].

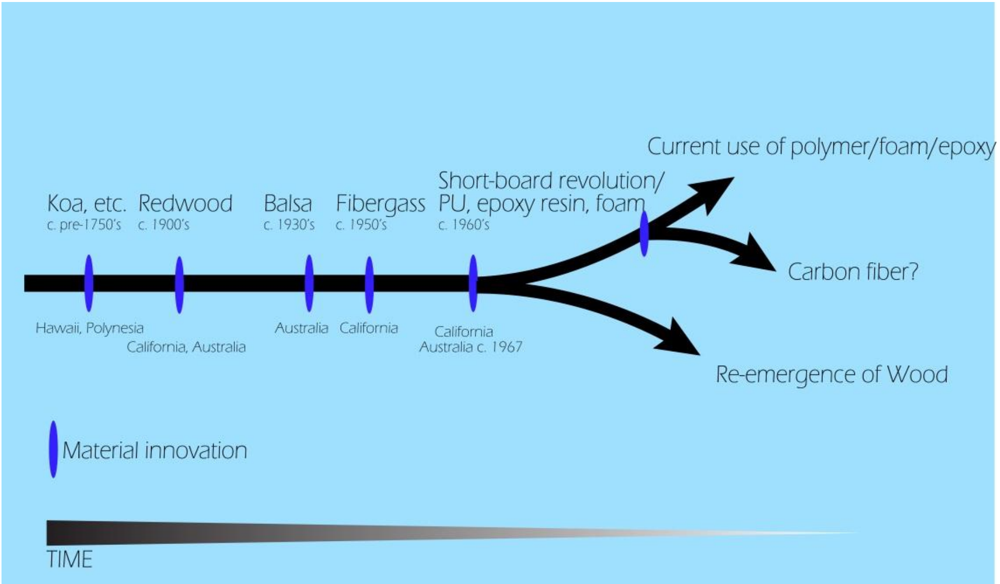


Figure 3 – Material innovation branching. Current variety includes polymer/foam use, carbon fiber (in its infancy), and the re-emergence of wood use).

The second major innovation area, Design, provided a much broader branching pattern (Figure 4).

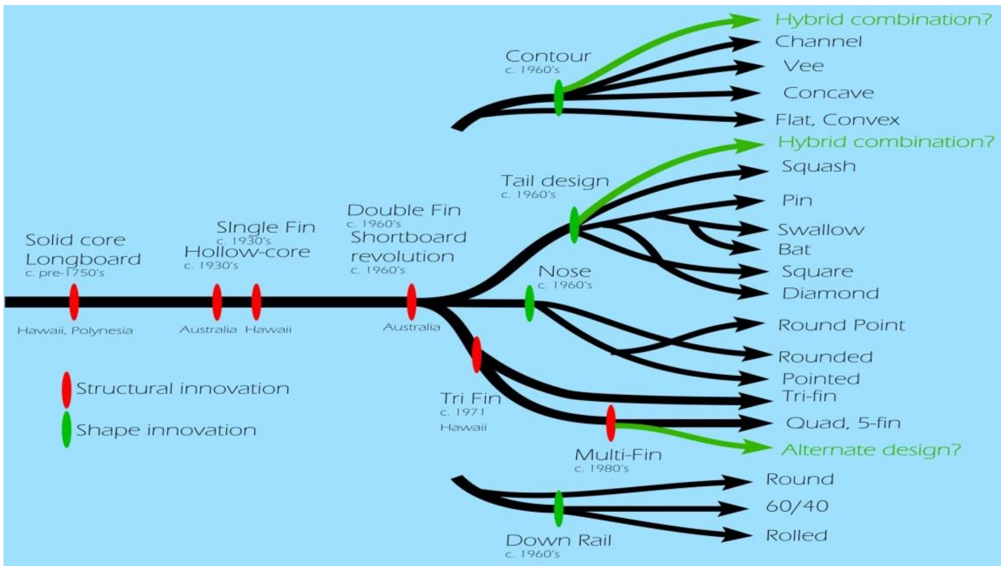


Figure 4 – Design innovations branch widely after the "short board revolution". Each area after 1960 does not overshadow previous innovations in a generational manner but rather exhibits a parallel path to all other innovations.

Design innovations post-revolution tended to branch and co-exist providing a “menu” of options one might combine to create a unique surfboard to provide a preference driven technological solution to a surfing style. The most innovative areas proved to be in this combination effort. Furthermore, combinations derived of existing designs often attempted to bridge performance benefits of each design. In Figure 4, the Diamond tail design branches from the Pin design and leads to the hybrid Square design. The diamond tail design is intended to combine the turning benefits of the Pin design while incorporating the speed afforded by the Square design [9][11].

Such hybrid styles might further push innovative designs into existence [12]; however, adoption is contingent on the performance benefits. The existing designs are widely distributed and utilized due to a wide acceptance of performance. If a design does not hold up to others, it might fail to diffuse. Contrary to a generational innovation however, if a hybrid design proves capable, then the specific solution the design provides to wave conditions and surfer preference would not be nearly as far reaching or prone to outclass older designs. It would merely become another accepted standard just as the other existing designs have. Herein, the innovation potential is high but contingent on performance. The assessment of the surfboard “space-time” showed that tail design, fin design, and bottom contour, had equal potential to create combination-based performance enhancements without generational innovation replacement.

In conducting the qualitative analysis on the branching of innovation and mapping the “space-time” of the surfboard as a technology innovation platform, the potential areas for possible future innovations were established. Combining these qualitative insights on innovation with the technological structure, a morphological analysis was conducted.

## 3.3 Morphological analysis

Morphological analysis was first pioneered by Fritz Zwicky, the Swiss astrophysicist, in his work with the California Institute of Technology. He was the founder of the Society for Morphological Research and applied this approach to many general topics including jet and rocket propulsion systems, legal aspects of space travel, and colonization. This approach has been extended by others including Tom Ritchey who applied this technique to political policy initiatives [15]. More recently, Yoon & Park used this method, combined with patent analysis and Conjoint Analysis, to forecast technological trends based on keywords pulled from patents [13].

This method has been shown to be very effective for analyzing technology choices in situations where the analysis is non-quantitative (e.g. subjective measures are involved). The approach requires examining all the elements of a “system” and then putting them together in all possible combinations and examining each configuration analytically to discover potential new technological advances. In his work at the Aerojet Corporation, Zwicky used this technique to find 571 potential propulsive power plants which had never before been identified in their labs – including two engines that were being experimented with by the British and the Germans.

However, one drawback to this approach is that as the number of system elements grows the number of possible combinations can grow exponentially. In fact, the pattern can really be calculated as a factorial. In other words, in a system with three components, and three choices for each component, the total combinations would number 3*3*3 or 27. By adding only one more element with three choices the potential combinations grows to 81. If this element had 10 choices the potential combinations would be 270 each of which would have to be examined "qualitatively" to see if it had the potential to provide an enhanced solution. Zwicky emphasized the virtues of being systematic, patient, and exhaustive in his research. While computers were available in the time of Zwicky much of this work was done by hand making it extremely labor intensive to do very large systems with many choices.

The process starts by identifying all the design elements of a system and the choices associated with them. In our earlier example, if we define s1 as the first element, s2 as the second element, and s3 as the third element, then we would have to examine: s1-1, s2-1, s3-1; s1-2, s2-1, s3-1; s1-3, s2-1, s3-1; s1-2, s2-1, s2-2, s2-3, and so on, until all combinations are exhausted. This collection of all possible choices is often called a "Zwicky box" (or Z Box for short).

One short cut that often used is to perform a cross-consistency analysis. The choices are placed into a matrix and then by doing a pairwise analysis all the choices that are clearly not feasible are eliminated. While the morphological model grows as a factorial as we add elements, the cross-consistency matrix only grows as a quadratic, so it is much easier to manage. Trimming inconsistent pairs can pull the overall model down to a much more manageable size.

In our analysis we started with the surfboard elements outlined in Figure 2. This diagram has 9 design elements with choices for those elements ranging between two at the low end (core: hollow or solid) and seven at the high end (tail: squash, square, thumb, pin, swallow, bat, and wing tail). We then took those elements and put them into a cross-consistency matrix. This matrix is included as Appendix C. This analysis shows that there are 90,720 possible combinations. The cross consistency matrix eliminates three combinations (solid core – carbon fiber, hollow core – PU-Fiberglass, hollow core – Epoxy-Resin), which trims our solution space, but still leaves us with a number that is far too large to analyze individually.

There is definitely value in breaking down the system and exploring the relationships at the system level; however, there is a great deal of untapped potential that could be hidden in the detailed relationships. The project team explored tools for automating this analysis but was not able to find any that were suitable. This may have to do with the short amount of time (relatively) allocated for this project or simply the fact that this is "qualitative" analysis. However, we did come up with an approach that we believe can overcome this limitation. This approach would involve a synthesis between morphological analysis and simulation. In the absence of simulation software we would use expert opinion or pairwise analysis.

In the ideal scenario we would use the computer to build each combination of elements (90,700 in this case), submit each set to a surfing simulation program which returns a score, and then rank the results by score. If we can develop a threshold score for acceptable solutions to consider this could reduce the number of combinations that require more detailed exploration.

Since we have not been able to locate a surfing simulation program that would work for this purpose we propose the following. We start with a series of potential outcomes that we are seeking: speed, maneuverability, or buoyancy. Then for each category, for example "tail", we have experts rank each alternative, in this case squash, square, thumb, pin, swallow, bat, and wing tail. We can either have them rank them 1-10 using a standard scoring model or use pairwise comparison to rank the alternatives for each outcome based on the attributes of speed, maneuverability, and buoyancy.

This approach will require votes on 35 elements in 9 categories rather than thousands making the problem far more manageable. Then we can sum the scores for each combination in terms of these three different outcomes and rank the results. The upside of this approach, besides creating a manageable solution set, is that adding new elements to the matrix, say a new style of fin, becomes relatively simple, we would only have to re-do the scores for the fin category, even though the size of the traditional model increases exponentially. We could also extend the model to rank combinations based on environmental factors such as wave size. This technique is also very general in nature so it could be applied to any other type of system where the elements can be scored by experts.

## 4. Conclusion

The surfing industry started as a sport for a privileged few and has evolved to be a multi-billion dollar sport that is enjoyed around the globe. The surfboard has evolved to keep pace with this expanding past-time. Starting with very heavy solid wood boards, evolving to hollow core and balsa wood boards, then boards made from polyurethane and fiberglass to reduce the weight and allow shorter, more maneuverable, surfboards. Although additional innovations can be seen on the periphery of surfboard design (fins, leashes, shapes, ..) technological innovation peaked in the 1960's and radical structural changes have not been visible since that time. In fact, based on environmental concerns we have seen a resurgence of some old designs, such as the balsa wood long board, with contemporary updates, returning to the market.

In terms of predicting the best technological changes moving forward we propose a version of morphological analysis combined with simulation (or expert analysis) to produce forecasts. However, this technique will require automated computer assisted tools to reduce the problem solution space to a manageable level. The development of this application and analysis will be performed in future research when time and resources are available.

In the meantime, this analysis provides Yāna Surf with the pattern of evolution in the surfboard industry, the current state of the art, and outlines the path for future research work on the technical evolution of the surfboard.

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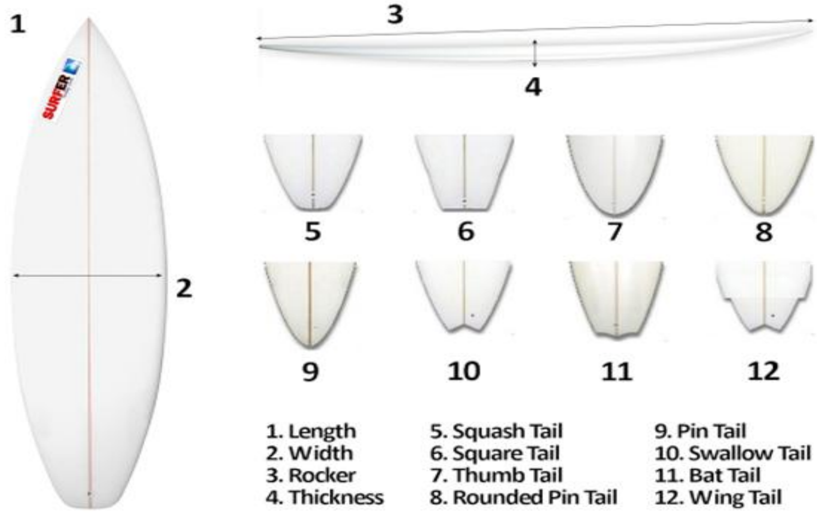
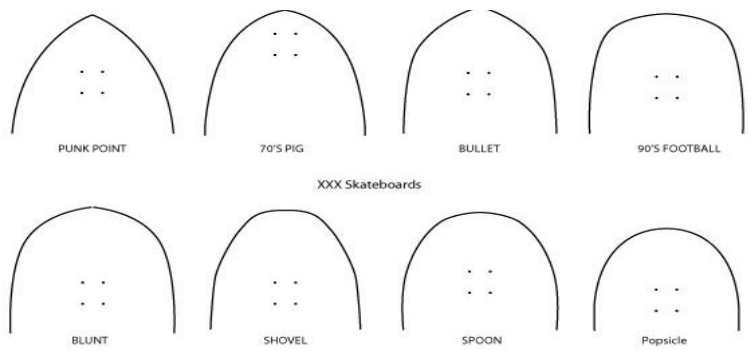
# Appendix A




Surfboard measurements and tail shapes




Nose shapes


Rail shapes


Fin shapes

# Appendix B

## *Table 1 – Technology and Innovation "Space-Time"*

| Innovation Area | Sub Innovation | Introduction timeframe | | Applications/Appeal |
|---|---|---|---|---|
| | | Place | Time | |
| **Material** | Koa, etc. | Hawaii | pre-1768 | |
| | redwood | Expansion | c. early 1900's | heavy, high momentum, faster, smoother |
| | Balsa | Cali, Australia, Hawaii | c. 1930-40 | lighter |
| | Balsa-Fiberglass | California | | |
| | PU-Fiberglass | California | c. 1950's to current | stronger, lighter, manuverability, shorter |
| | Epoxy Resin | | c. 1980's to current | |
| | Balsa-Foam core | | current | |
| | Popout foam boards | Australia | c. 1970's | Easy to manufacture, chearper, more accessable, safer |
| | Carbon Fiber | | current | ultra-light weight |
| **Core** | Solid Core | Original designs | | Solid, heavy build |
| | Hollow Core | Hawaii | c. 1930's | environmentally friendly, faster, lighter |
| | Foam (PU or PS) core | California | c. 1960's | increased buoyancy |
| **Length** | Short Board (6'2" - 6'6") | Australia | c. late 1960's | Increased manuverability, small wave surfing, easy to ride |
| | Fun Board/Gun (7'2" - 7'10") | | | Easier to catch waves, manueverable, fast (combines long and short attributes), can be used for big-waves |
| | Long Board (8'6" - 12') | Malibu, original | c. 1900's in modern form | Stability, faster, ease of catching waves |
| **Thickness** | 2.5" | | | |
| | 3.0" | | | |
| | 3.5" | | | increased buoyancy |
| **Tail** | Squash Tail | Global Distribution | Shortboard revolution | provides drive without sacrificing manueverability |
| | Square Tail | | Shortboard revolution | provides less release on turns, faster design |
| | Thumb Tail | | Shortboard revolution | Provides smooth turning in average surf conditions, increases surface area allowing more contact for stable turns |
| | Pin Tail | | Shortboard revolution | Creates a point to pivot on, stable, sensitive turning capabilities, big wave surfing |
| | Swallow Tail | | Shortboard revolution | small wave manuverability, corner-holding |
| | Bat Tail | | c. 1990's | provides extra pivot points for turning, increased stability over swallow tail |
| | Wing Tail | | Shortboard revolution | provide hold for wide tailed designs, allows for more control during high speed turns |
| **Nose** | Pointed Nose | | | common to short board |
| | Pointed Round Nose | | | safety innovation |
| | Round Nose | | | common to long board |
| **Rocker** | Low Rocker | | Shortboard revolution | wider turning radius |
| | Medium Rocker | | Shortboard revolution | |

| | | | | |
|---|---|---|---|---|
| | High Rocker | | Shortboard revolution | smaller turning radius |
| **Rails** | Round Rail | | Shortboard revolution | |
| | Down Rail | | Shortboard revolution | provides holding power in turns, |
| | Rolled Rails | | Shortboard revolution | |
| | Egg Rails | | pre-shortboard | suited for convext bottoms and roll |
| | 50/50 | | pre-shortboard | suited for convext bottoms and roll |
| | 60/40 | | Shortboard revolution | |
| **Bottom contour** | Flat Bottom | | pre-shortboard | Limited stability, lift or leverage, often combined with other contours |
| | Convex Bottom | | pre-shortboard | greater lateral stability, forgiving, better handling |
| | Concave Bottom | | Shortboard revolution | lift producing design throughout, design is highly dependent on user preference |
| | Channel Bottom | | Shortboard revolution | very quick acceleration, fast, ideal for point or reef breaks |
| | Vee Bottom | | Shortboard revolution | Variability in turning radius, good lift, forgiving in turns |
| **Fin system** | Single Fin | Hawaii | First appearance 1935 | allows pivoting, lateral stability, allowing surfer to follow the curve of the wave |
| | Double Fin | Australia | c. 1960's-70's | Used mostly on shortboards, adjustable to fit the desires of the surfer |
| | Triple Fin | Hawaii big-wave | Emergence 1971 | Better turning capabilities, greater thrust, combines glide and performance, control in bigger surf |
| | Quad Fin | | | Quick down the line, loss of drive through turns |
| | Quad + Fin | | c. 1980's to 1990's | |
| **Ankle Leash** | | | Emergence 1971 | Allowed for surfers to stay near boards in case of wipeout |
| **Wet Suit** | | California | c. 1950's | Allowed for year-round surfing |

# Appendix C

See the spreadsheet titled Appendix C – Cross-Consistency Analysis.

Possible Combinations: 90,720

| | | Material | | | | Core | | Length | | | Thickness | | | Tail | | | | | | | Nose | | | Rocker | | | Rails | | | | Bottom Contour | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Balsa-Fiberglass | PU-Fiberglass | Epoxy-Resin | Carbon Fiber | Solid Core | Hollow Core | Short Board (6'2" - 6'6") | Fun Board/Gun (7'2" - 7'10" | Long Board (8'6" - 9'6") | 2.5" | 3.0" | 3.5" | Squash Tail | Square Tail | Thumb Tail | Pin Tail | Swallow Tail | Bat Tail | Wing Tail | Pointed Nose | Pointed Round Nose | Round Nose | Low Rocker | Medium Rocker | High Rocker | Round Rail | Down Rail | Rolled Rails | Egg Rails | Flat Bottom | Convex Bottom | Concave Bottom | Channel Bottom | Vee Bottom |
| Core | Solid Core | c | c | c | i | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Hollow Core | c | i | i | c | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Length | Short Board (6'2" - 6'6") | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Fun Board/Gun (7'2" - 7'10" | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Long Board (8'6" - 9'6") | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Thickness | 2.5" | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3.0" | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3.5" | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tail | Squash Tail | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | |
| | Square Tail | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | |
| | Thumb Tail | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | |
| | Pin Tail | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | |
| | Swallow Tail | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | |
| | Bat Tail | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | |
| | Wing Tail | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | |
| Nose | Pointed Nose | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | |
| | Pointed Round Nose | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | |
| | Round Nose | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | | | | |
| Rocker | Low Rocker | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | |
| | Medium Rocker | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | |
| | High Rocker | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | | | | |
| Rails | Round Rail | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | |
| | Down Rail | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | |
| | Rolled Rails | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | |
| | Egg Rails | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | | | | | |
| Bottom Contour | Flat Bottom | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | |
| | Convex Bottom | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | |
| | Concave Bottom | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | |
| | Channel Bottom | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | |
| | Vee Bottom | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | | | | | |
| Fins | Single Fin | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c |
| | Double Fin | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c |
| | Triple Fin | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c |
| | Quad Fin | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c |
| | Quad + Fin | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c | c |