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# Design and evaluation of functional gear for protection, fit and mobility

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# Design and Evaluation of Functional Gear for Protection, Fit and Mobility

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ABSTRACT

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*Functional wearables are a growing field at the intersection of fashion and technology. This research centers on the conceptual development of a fastening system in a functional wearable - fishing footwear - by assimilating utilitarian design values in a product design model. A project-based research methodology utilizing an iterative design process was used to create a multifunctional and technologically enabled closure system in fishing footwear.*

*As part of the planning phase, an extensive review was conducted. This exploration substantiated the need for research centered around fastening systems for fishing footwear. A thorough investigative study was conducted as part of research phase including elaborate market reviews, hands-on test findings, analysis of various shoe closures and existing technologies. Five illustrative design concepts for fishing footwear fastening systems were created based on various ideations from outdoor products such as helmets, bag-packs, gaiters, etc. One fastening concept was selected using feedback from footwear design experts. The instrument (questionnaire) was developed emphasizing fit, protection and mobility parameters with a retail perspective for the proposed design concepts.*

*As part of concept detailing phase, an intricate 3-D projection model and detailed technical specification sheet was developed adherent to design standards used in the footwear industry. This detailed design was henceforth validated through decision matrix analysis utilizing feedback from experts. In addition, an extended application of the shortlisted design solution in other outdoor gears was illustrated for demonstrating its generic utilitarian significance.*

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CHAPTER I

# Introduction

*"Give us the tools and we will finish the job"*

*- Winston Churchill*

This quote reflects the importance of constant innovation in tools and gears for specialized activity. The new economic environment, characterized by the globalization of markets, pressures designers to stay competitive by providing their customers with as much added value as possible. Consumers demand functionality, expect usability and are seeking products that elicit other feelings such as pleasure or that strike a certain emotional chord. Innovation is then regarded as a continuous process which enables companies to respond optimally to existing market dynamism. Daniel et al. (2007) emphasizes the importance of innovative tools in product use is fast becoming of primary importance to both consumer and the design industry alike. Especially with the design of outdoor products, activities of the consumer drive the innovation associated with the gear. Outdoor sports activity puts a significant demand on the designers to identify opportunities in creating new tools.

Not only is the industry calling for creative and functional innovations, but the demand for new and functional outdoor products continues to rise. According to the Outdoor Industry Association (2012), more than 140 million Americans make outdoor recreation a priority. This fact is illustrated by the over $646 billion that was spent on outdoor products in 2012 (Outdoor Industry Association, 2012). Outdoor recreation is a growing and diverse economic super sector that is a vital cornerstone of successful communities that cannot be ignored. At the core of the

outdoor recreation economy is the outdoor consumer, whose diverse interests fuel a robust and innovative industry. Today's outdoor lovers are not confined to traditional demographics or activity segments. They seek meaningful outdoor experiences in their backyards and in the backcountry. They are all genders, ages, shapes, sizes, ethnicities and income levels. They live throughout America, and they view outdoor recreation as an essential part of their daily lives. They fill their garages with bicycles, dirt bikes, backpacks, boats, skis, tents, hunting rifles and fishing gear. This is redefining the outdoor industry, an evolution that is evident in the growth of sales and jobs since 2006. Gear purchases include anything for outdoor recreation, such as outdoor apparel and footwear, bicycles, skis, fishing waders, tents, rifles or backpacks (Outdoor Industry Association, 2012).

Outdoor product design is morphing with the activity needs and the ever-changing whims of designers and marketers. Thus, with the focus on the creation of thousands of fashions for only few basic styles of shoes, there have been only relatively minor advances in the most basic elements of footwear, namely fit and support, the two features that together make for foot comfort (Czelusta, n.d.). Despite progress by industry, a new national survey by Eneslow®, The Foot Comfort Center suggests that 25% of the shoes Americans own are too uncomfortable to wear(Kelton Research, 2009).

Actually, consumer expectations and needs demand development of footwear that integrates fashion, emotional desires and real functional performance (Duquesne, Magniez, & Camino, 2007). Footwear is one of the most used types of consumer products which act as much more than a simple fashion statement, where consumers are looking for flexibility (Kyllo & Hudson, 2015). Rather than hyper-specific use shoes, outdoor enthusiasts are looking for

solutions that go seamlessly from water to the trails to the streets. Composed of a large number of components, footwear has many modes for potential failure which represent a safety risk to the user. Just like tires on a vehicle are the only points of contact with the road and therefore are critical in avoiding accidents, footwear is a consumer's point of contact with the ground and is similarly critical (Kyllo & Hudson, 2015).

Comfort is the number one factor that people look for, especially in outdoor footwear, with 88% citing that as most important (Lapine, 2015). This factor is claimed to be of utmost importance in wading boots, making them one of the most important pieces of fly fishing gear an angler owns (Guide to Wading Boots, n.d.). Without a good wading boot (or shoe), the angler is as likely to end up swimming with the fish instead of trying to catch them. Since an angler is likely to wear their wading boots throughout the day, a heavy and ill-fitting wading boot is a recipe for an unpleasant day of fishing. Shoes often are overlooked as part of an angler's preparation. Again, finding the best fishing boots is a tough challenge for most anglers looking for that perfect pair to provide warmth and offer ultimate protection for their feet when fishing in adverse conditions (Funt, n.d.).

A great deal of research has been conducted on personal protective equipment (PPE) for sports in terms of thermal comfort and protection (Bye & Hakala, 2005); (Crown & Dale, 2005); (Tan, Crown, & Capajack, 1998), while little attention has been given to the fishing footwear in the outdoor sports industry addressing concerns of protection. There is a growing popularity of fly fishing and the sport's broadening appeal has not gone unnoticed for a long time now. A spokesman for Trout Unlimited (conservation group in Vienna), Peter Rafle said, "We are all feeling the buzz of what is going on, because the rivers are getting more crowded" (personal

communication, n.d.). A similar mention by Joe Coopy, Director of the American Fishing Tackle Manufacturers Association, stated that, "Fly-fishing has become something of a cult. The current surge is especially noteworthy because it comes amid a waning interest in general fishing gear, which has led some major retailers, including J. C. Penney and Sears, Roebuck & Company to phase out the equipment" (personal communication, n.d.). Reliable statistics on fly-fishing equipment sales are not available, because most manufacturers are small and privately owned. It is estimated that annual sales range between $100 million and $200 million and have been growing annually over the last four years by about 15 percent in fashion (Meier, 1993). With the growing popularity of this sport, the awareness was raised to design better footwear with improved protection, comfort and fit for the fishing folks.

According to the famous writer and conservationist, Roderick Haig-Brown (personal communication, n.d.), fishing is one of the keenest and best-wearing pleasures of life. Fishing may be the most enjoyable outdoor activity. This is precisely why the fly-fishing business is in a constant boom. As it is assumed, fishing is hardly a dangerous sport. Yet, every year, anglers end up hobbling into a hospital with a sprained or broken ankle due to tumbling into the river unexpectedly. While not all tumbles can be avoided, most falls can be prevented by simply wearing a wading boot that provides solid protection with wet, slippery rocks.

Fishing footwear is prone to unique requirements and conditions (Guide to Wading Boots, n.d.). The anglers are likely to wear wading boots throughout the day, requiring the boots to be lightweight and well fitted. In addition, the shoes may be subjected to various adverse conditions including temperature variations such as sudden drop in water temperature, icing, etc. requiring extended thermal protection; prolonged contact with water requiring water resistance;

rough terrains including rocks, pebbles, sand, mud, etc. requiring robust cushioning and secure fastening systems; exposure to adverse plant and animal species such as poisonous hydrous plants, fishes, etc. requiring advanced non-invasive materials. In this study, efficient fastening systems for fishing footwear were focused on – the need for which cannot be trivialized (Guide to Wading Boots, n.d.). This has helped identify a niche exploratory idea within the realm of many possible functional wearable in outdoor gear industry.

Functional and aesthetic innovations in fastening systems of wading boots are yet unknown and worth in-depth research. Many of these innovations fall under the realm of "wearable technology" that can be defined as the seamless integration of function and technology into the fabric of our daily lives. As discussed, anglers have continued to endure safety and fit issues with their footwear because of their unique conditions posed during fishing. This project-based research study will propose a design for a novel, utilitarian fastening concept in fishing footwear, which is conceptualized to offer optimum protection, fit and mobility to anglers.

**Conceptual Framework**

Project-based research shares some core values with the "project-based learning" educational model. It is a useful technique for researching design and development because it requires the researcher to create a need to know essential information, use problem solving and various forms of communication and incorporate feedback and revision.

More innovative solutions focused on user needs can be delivered through the Iterative Design Process based on research and experimentation (iterative design process cycle). Iteration in the conceptual design stage is defined as repetition of design tasks to incorporate new

information. A more concise definition of iteration relevant to this research would be the progression of design through different abstraction levels or design stages, defining and refining design solutions while progressing from initial concepts to a more detailed design (Karthik & Ranganathan, 2013). This concept of "iteration" (defined above) is considered an integral part of any design activity and a natural attribute of design competency. As a symbolic feature in models of design activity, iterative cycles illustrate a process of revisiting and resolving aspects of a design task. In addition, iteration may be modeled as a goal-directed activity that involves gathering and filtering problem information, monitoring progress and understanding, and revising possible solutions (Adams, 2001). Such an iterative design process was implemented to make aesthetically appealing footwear that offers improved fit and mobility for fishermen (see Figure 1).

This process model organizes the problem solving process into four categories: problem finding (observing and research), problem selecting (reframing and contextualizing), solution finding (converging and establishing core user needs) and solution selecting (experimenting and prototyping) (Owen, 1998). In short, the cycle of a design thinking process evolves through "what is" in reality (context), is then distilled to a model of "what is" (insight) and a model of "what could be" (idea), which in the end manifests in a "what could be" solution (artifact), for instance a prototype or an intervention (Barry & Beckman, 2008).

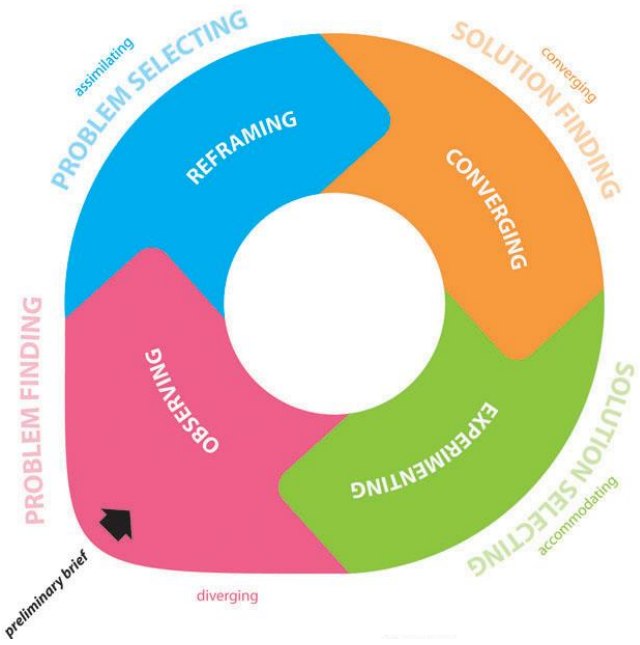



Figure 1: The Iterative Design Process Cycle (Barry & Beckman, 2008)

**Purpose and Objectives**

This research aims to create a novel, utilitarian fastening concept in fishing footwear with innovative objectives, where theoretical constructions and practical explorations of various forms of fastening are the core of the research. Efforts are made towards generating design solutions through iterative design process to meet the needs of the consumers (improving fitting, protection and mobility). The detailed objectives of the study are summarized as follows:

- Understand the functioning requirements of fishing footwear closure systems
- Identify design issues through user reviews and market research reports
- Find a conceptual design-solution through innovative ideations and expert selection
- Transform the product concept into a design-for-manufacturability prototype

**Limitations**

This study is primarily limited to the non-proprietary sources, i.e., open literature, company white papers, online reports, technical sheets, patent filings, etc. and interaction with

related market experts willing to share the data in the need exploration and process investigation. Since industry personnel are involved, some confidential or proprietary information, which might otherwise be valuable to the research, was not obtainable or remained undisclosed. Some opinion bias may occur if similar or competing technologies were utilized within the company as that proposed in this study.

Also, in examining the importance of employing the application based iterative design process to design fishing boot, the involvement of external sources had created minor hurdles. Some examples of these are:

- The coordination of market professional involved significant effort.
- In many cases, lack of adequate elaborative product reviews from the consumers, with regards to functioning of the fishing boot, was apparent.

CHAPTER II

## Review of Literature

Much of the literature related to product design and development is in closed form and confined to industrial white-papers or publications. Among those which are available in open sources are affiliated with academic research or industrial management forums. The review has been broadly classified according to various research topics pertaining to this study, for e.g., types of fishing shoes and boots, fastening systems in other functional gears, concerns about conventional fastening systems, fitting issues, mobility issues and protection issues, etc.

The next section provides a generic review of various types of fishing shoes and boots currently utilized by the angler population. This review has been categorized based on different types of fishing activities which are used on different terrains. The subsequent section gives a review of conventional fastening systems commonly used within footwear domain and identifies limitations in context of fishing footwear. The section following this goes into the specifics of fastening systems used in sports and protective gears and identifies how existent fastening systems are correlated to functional aspects and environment conditions of specific sport or required protection. This review also helped assess gaps in closure systems distinctive to fishing footwear functional requirements. A brief review of medical footwear enclosure, in the subsequent section, provided a fresh perspective on podiatric requirements and limitations, including types of medical issues encountered due to adverse and/or prolonged foot conditions. The last few sections discuss the importance of fit, mobility and protection in functional footwear including that of fishing shoes/boots, and serves as an important cog in the wheel within the context of this review. The extensive review was directed towards establishing a need

for current research around fastening systems for fishing footwear, which also provided a rationale for choosing this area of study.

**Types of Fishing Shoes and Boots**

In today's marketplace, there is a wide variety of shoes and boots available for all different types of fishing. Specialized water footwear offers benefits the average athletic shoe cannot. First, this type of footwear provides excellent traction, keeping the wearer safe on wet, slippery surfaces. Water footwear provides a high level of comfort as well, since it does not become soaked or waterlogged once submerged. Water footwear is also specifically designed to be durable, preventing mold problems or breakdown of materials due to constant immersion in the water. No specific shoe is ideal for every situation, but most captains recommend wearing at least some type of footwear as protection (Hudson, 2016). Hooks, knives, gaffs, tag sticks, pliers and spastic fish can easily damage vulnerable feet of the anglers.

First, it is important to understand that there are different types of fishing shoes which are made to use on different terrain. Each fisherman has different criteria to choose their best fishing shoes. There are conditions like environment and nature to influence the decision. Hence, it was very important to consider noteworthy features of each type of fishing shoe for performance assessment. Furthermore, it helped in identifying the needs of a fisherman with respect to various shoe closures. A few categories of fishing footwear are mentioned briefly in the following:

**Fly fishing:** When heading out into fly fishing streams and rivers, it is necessary to have a good pair of waders. Wading boots are specifically designed to be used for fly fishing. Waders essentially are a durable, waterproof suit that pulls on over clothing like a pair of pants and usually has straps that go over the shoulders, like overalls. Waders allow the fly fisherman to stay

dry while wading to his or her location in the river. These waders are lightweight, and when coupled with a wading boot is a great choice for those who walk or hike moderate to long distances to reach their fishing destination (Hudson, 2016). It is important to find wading boots that are comfortable, durable, and waterproof, so they withstand lengthy amounts of time in the water. Wading boots should also have excellent traction on the bottom to prevent the user from falling on slippery rocks while fishing.

**Canoe and kayak fishing shoes:** On the other hand, kayak fishing shoes are lightweight, have good soles, and stick to the leg when pushing through the sticky mud. Kayak shoes are specifically designed to quickly drain water, and do not absorb or hold water(Outdoor sports gear reviews, 2015). This gives the fisherman a large advantage, as he or she can avoid waterlogged and squishy feet. The ability to drain water allows the water shoe to remain lightweight in and out of the water, as well as keep the fisherman's feet warm and dry.

**Boat fishing:** These are quite similar to the kayak and canoe fishing shoes; and are ideally lightweight which drains the water quickly (Afsar, 2015).

**Shore Fishing:** Fishing shoes ideal for this activity are lightweight and have high breathability. They are a great choice for fishermen finding themselves in and out of the water frequently. Someone looking for a shore fishing water sandal should consider foot protection, and select a pair that provides good coverage on the top of the sandal, as well a strong toe cup at the front. This will provide a bit of cushioning for the foot in case something drops on it or if the user stubs his or her toe (Big Sky Fishing, n.d.). Lastly, water sandals are designed with antibacterial fabrics to ensure their durability because they go in and out of the water so frequently.

**Conventional Fastening Systems**

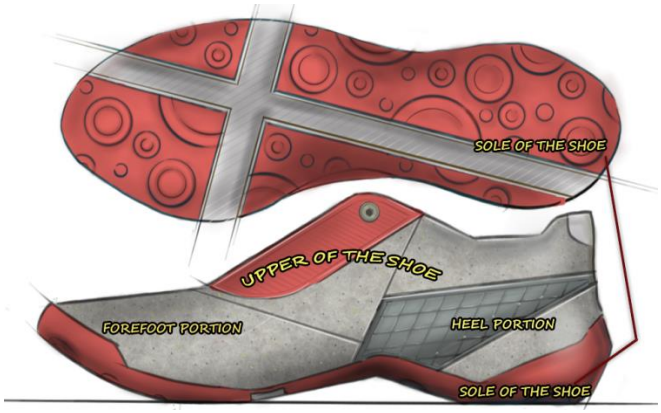



Figure 2: Basic structure of the shoe illustration

A conventional article of footwear includes two primary elements; an upper and a sole structure (see Figure 2). The upper provides a covering for the foot that securely receives and positions the foot with respect to the sole structure. The sole structure is secured to a lower portion of the upper and is positioned between the foot and the ground. The sole structure may attenuate ground reaction forces, provide traction and control foot motions. The uppers of many articles of footwear, including most articles of sports and outdoor footwear include a forefoot portion and a heel portion (see Figure 2). These uppers generally include an opening that may be enlarged to receive a foot and then reduced or tightened to assist in the retention of the article of footwear to the foot. A variety of closure systems are used to enlarge and reduce the foot-receiving opening.

Fastening or tightening objects by means of strings or laces is well known. Typically, a string or lace is run through a series of holes on opposing sides of an article to be secured together, and the free ends of the string or lace are then pulled to bring the opposing sides together. Shoelaces are not the only means of fastening a shoe. For instance, hook and loop bands (Velcro) are commonly used as a fastener on shoes. A Velcro flap or a plurality of Velcro

flaps are generally affixed to either the left or right side surface of the shoe. The Velcro band is pulled across the top of the shoe in a left to right or right to left direction and engages with a corresponding Velcro band affixed to the upper surface of the shoe. “This type of fastener also has drawbacks. For instance, the noise made by the hook portion of the Velcro being pulled from the loop portion is unpleasant and disruptive. In addition, the Velcro can become loosened during wear. Further, in order to achieve sufficient tightness, the Velcro needs to be reengaged for each use, and, consequently, disengaged each time the user removes his shoe. The constant engaging and disengaging of the fastener eventually weakens the Velcro. Thus, the shoe must generally be discarded when the Velcro fails because the Velcro is permanently affixed to the shoe” (U.S Patents, 2013). Thus, the replacement cost of Velcro is significantly higher than that of a shoelace.

**Fastening Systems in Sports and Protective Gears**

Fly fishing is an old and classic pastime, but in many ways no different from other industries. If the terms “shoelaces and running” or “shoes and biking” are used in an online search engine and one thing becomes very clear—many athletes are obsessed with shoe fastening devices (Pal, 2015). Of course, athletes have good reason to be captivated by closures—a good footwear fit can enhance an athlete’s function, while a less than ideal shoe fit may spell trouble.

“User wants a shoe that is going to optimize performance, so the closure should enhance the shoe’s fit and function,” said Rob Conenello, (former president of the American Academy of Podiatric Sports Medicine); “no one wants a closure that’s new and trendy if it takes away from performance” (personal communication, n.d.)

Sporting goods companies continually innovate and release new gear, driving consumers to buy the latest boots and reels. There is plenty of good–even great–fly-fishing gear introduced every year (Burke, 2010). But in particular, footwear closure configurations have not changed much over the last 50 years. The location and opening configuration has evolved into a convention that now may be considered to constrain novelty (Sparks, 2012). Boot lacing systems are still the preferred method of closure. There are and have been other systems tried within performance footwear.

Patented mechanical closure systems, over-locking clamps (typically used on ski boot systems); and hook and loop-based fastening systems have all been applied to extremities protection. Handwear closures are still predominantly buckles, buttons or hooks. The only innovation has been in hook and loop fastening. However, this novel means of personal protective equipment (PPE) closure is prone to wear and the loop base being clogged by mud and other contaminants. The perceived tightness when using a PPE locking system is an issue still not fully addressed in conventional closures. Buckle and button systems provide a crude discrete circumference length adjustment, whereas hook and loop, lacing and cleat-based buckles have variable adjustment; however, lack of feedback to the user about the amount of adjustment made can cause problems in use.

In case of cycling shoes, either a Velcro strap system or a buckle/ratchet system is mostly used (Hughey, 2013). The Velcro strap is easy to use and will hold up well in dirt and water. A buckle/ratchet system is usually best for durability and gives the most secure fit. Most shoes with a ratcheting buckle will feature a single buckle on top with two Velcro straps below. Laces are also more likely to stretch, get dirty and, wear out. Still, bikers like laces because they make

the shoes look more like hiking shoes and not clunky bike shoes (Hughey, 2013). Cycling shoes with lace fasteners usually provide a pocket in the tongue for tucking your laces away. This will keep them from getting caught in the chain.

The safety performance of general footwear is critical in offering the consumer the best protection against injury during normal use. Footwear is constructed using many different components and methods. It is necessary to assess footwear as finished products to determine if they are sufficiently stable to withstand the stresses of wear (Kyllo & Hudson, 2015).

**Medical Perspective in Shoe Closure Systems**

There is a growing popularity of footwear with alternative closure systems, such as Velcro, straps, no-tie shoelace replacement systems, and slip-ons, according to the retailers (Pal, 2015). As stated by David Armstrong (personal communication, n.d.), Director of the Southern Arizona Limb Salvage Alliance at the University of Arizona in Tucson, "anything having to do with footwear fastening is fifty-one on our list of the fifty most important things we need to think about". He further pointed out that an average person is probably taking several thousand steps a day, leading to a fair amount of repetitive stress across the foot and closure systems can play a role in ensuring that footwear is effectively doing its job.

Figure 3: Clutch reel systems have become popular with athletes and may have benefits for patients with diabetes and other conditions. (Photo courtesy: venturethere.com.)

The footwear industry has made an effort to encourage people to pay more attention to shoe closures by offering alternatives to lacing, including Velcro, no-tie elastic systems, and clutch reel technology. But the question is whether these types of closures are destined to replace shoelaces. While laces are best for keeping the shoe firmly placed on the foot, a good Velcro or other closure type, such as elastic no-tie shoelace replacement systems, can do the job just as well, said Russell Volpe, Professor at the Foot Center of New York, an affiliate of the New York College of Podiatric Medicine in New York City (personal communication, n.d.).

Clutch reel closure systems feature steel laces, nylon guides, and a mechanical reel that allows the user to adjust the fit by turning a knob. One benefit of this system is that it gives the wearer a better idea of whether the shoe is on too tight or not tight enough, especially if the

optimal level of tightness is preset by a foot health professional (Armstrong, personal communication, n.d.). That is exactly why Armstrong and his colleagues are conducting an ongoing study that compares shear stress on the feet of patients with diabetic peripheral neuropathy with an orthopedic shoe outfitted with a clutch reel closure versus a regular shoe with laces. Their theory states that a reduction in shear force associated with the clutch reel technology will ultimately translate to better foot health, especially in patients with diabetes who are at risk for ulceration (Owl, Marin, & Enriquez, 2015). The researchers used a thermal response to stress test to assess shear force, and compared three shoe closure conditions: loose laces, tight laces, and optimal with the clutch reel, explained Najafi, Director of the Interdisciplinary Consortium on Advanced Motion Performance at the University of Arizona. In the study, a clinician predetermined the level of optimum shoe fit. The wearer had only to turn the knob to the set level of tension. If they went past the predetermined setting, the knob would simply spin, but wouldn't cause the shoe to tighten excessively (Armstrong, personal communication, n.d.).

It is ultimately reported that too-loose and too-tight conditions significantly increase thermal response to stress when compared to optimum shoelace closure, but when using the clutch reel, thermal response could be reduced compared to what subjects thought to be optimum shoe lace tightness (Owl, Marin, & Enriquez, 2015).

The diabetic foot and the clutch reel closure is a symbiotic match. Patients with diabetes often have circulatory restrictions in the lower extremities, which increase the risk of foot ulcerations. The clutch reel system would theoretically eliminate the guesswork that goes with adjusting laces. Having the opportunity to adjust to an optimum closure, retain it during daily

physical activities, and ensure that patient cannot make their shoelace either too tight (which may limit skin perfusion) or too loose (which may increase shear force) and has the potential revolutionize diabetic footwear and contribute to reducing the risk of diabetic foot ulcers. Ease of wear, ease of fastening, and limited effort to maintain a consist fit are major factors in ensuring patient compliance with prescribed footwear.

Over the years, athletes have moved away somewhat from traditional lacing, gravitating toward other options, such as elastic-covered lock laces or clutch reel systems (Pal, 2015). Athlete or otherwise, the goal is to achieve what Rob Conenello, global clinical adviser to many athletes in Olympics (personal communication, n.d.), referred to as “a neat fit”. Everyone learns

Figure 4: A heel lock modification, sometimes called a runner’s loop or lock, utilizes the top two shoelace holes for a better fit. (Photo courtesy: Rob Conenello, Podiatrist)

to tighten shoes up from the distal aspect of the shoe and pull hard until the shoe feels tight, but that is not necessarily ideal. A neat fit around the forefoot is defined as a fit where the shoe feels secure, i.e., comfortable but not tight. Also, a lot of people are unaware what the extra (lace) holes at the top of the shoes are for so they don't use them properly. The lace may be threaded through the holes to cinch the shoe, if an individual's heel feels slipping out of the shoe. This technique is sometimes called a heel lock modification, or a runner's loop or lock.

Kevin Fraser, President-elect of the Pedorthic Association of Canada in Winnipeg (personal communication, n.d.), also said he stresses the fit of the shoe overall, rather than the closure style. He often sees people being fitted with the wrong type of shoe for their foot type, which can reduce the effectiveness of the shoe's closure system. An example of that would be a person with a very high arch who is fit with a shoe that is too shallow and, as a result, the opening of the shoe doesn't close and secure the foot properly in the shoe. Conversely, (in the same type of patient) if the opening is too narrow, it puts too much pressure on the foot.

Laced shoes offer more options for adjustment than a Velcro closure. Velcro may be quicker, but does not necessarily provide the type of customized fit that laces do. "With a lace shoe, one can control the pressure over the foot better than one does with Velcro strap because we can tighten or loosen the laces," Fraser explained (Personal Communication, n.d.). The user also has more options in the way laces are threaded and tied. However, it is acknowledged that some people may not have the capacity for or even interest in dealing with laces, and practitioners need to take that into consideration. For example, if a patient is given a pair of laced shoes, but then proceeds to put on the shoes by "stamping" down the back of each one and turning them into a slip-on, it will ultimately destroy the footwear and render it ineffective. In

those cases, better adjustability may be sacrificed with the laces by providing them a Velcro shoe, because it’s simpler to use, and that increases the likelihood that they will wear the shoes.

As a conclusion, if a shoe no longer seems to fit properly, podiatrist suggests to change the laces instead of changing the shoes. In case of any medical conditions or seeking extra convenience or adjustability, users may seek out a different closure type (Conenello, personal communication, n.d.).

**Fitting issues**

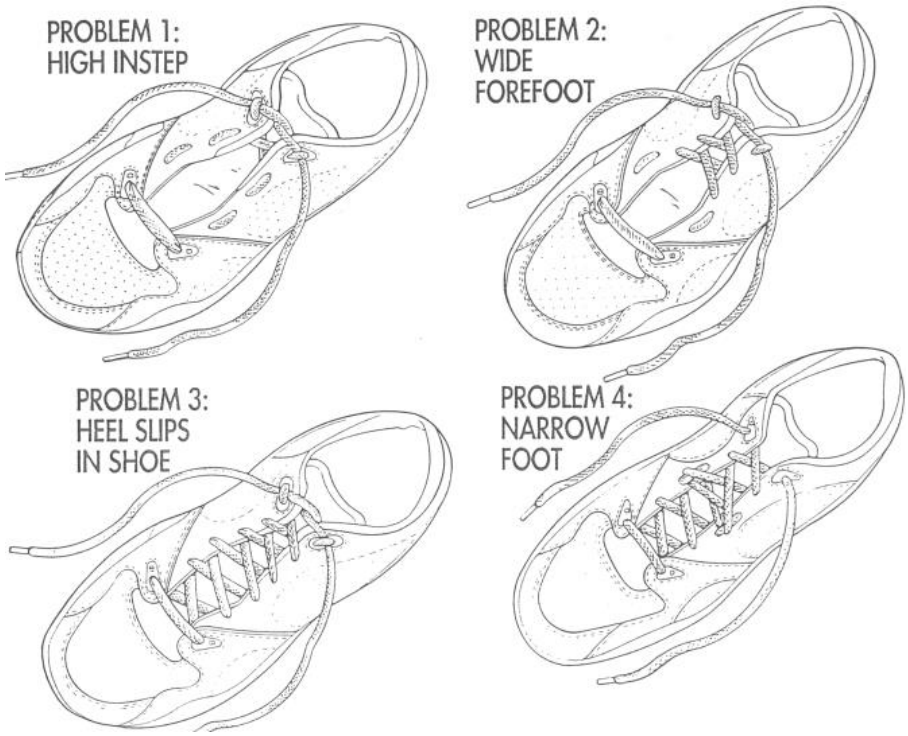



Figure 5: Lacing techniques for different fitting adjustments (Podiatryclinics, n.d.)

Namely, as the material of the footwear itself is worn over time it becomes broken in, causing a looser fit, which the user can compensate for by tying the laces tighter. In other instances, the user's foot may swell slightly during the course of the day, and the user may accordingly loosen the laces a desired amount to accommodate the swelling. A true custom fit is

thus achieved each time the footwear is worn. Another advantage with using laces as a fastening system in footwear is that they typically provide greater strength than zippers or hook and loop fasteners, both of which are prone to breakage and failure, especially during vigorous athletic activities which impose high tensile forces upon footwear's fastening means. According to Nike (2014), some articles of footwear may eliminate lacing adjustment systems, such as slip on shoes. However, these articles of footwear are not able to be tightened and loosened on the wearer's foot, which may lead to an imperfect fit.

Neale (2012) stated that "however, conventional lacing systems have some disadvantages over other fastening means. For example, tying laces is typically more time consuming than using, e.g., a zipper, and also involves a degree of skill and manual dexterity to create a proper knot of sufficient tightness and end loop lengths to ensure the knot will not be too easily untied. In the case of footwear, laces also add bulk to the top of a shoe, especially due to the knot and/or free end portions of the lace. Furthermore, laces often nevertheless become untied, sometimes repeatedly, especially when the user engages in outdoor activity, particularly in sports. In footwear, this creates a hazardous situation for the user by increasing the risk of tripping, thus requiring the user to stop, bend down and retie the lace before being able to return to the activity". While extra knots could be employed to prevent a lace from become untied during use, this is often undesirable as it increases the difficulty and time in both securing and releasing the article, as well as adds additional bulk (e.g., to the top of a shoe).

Lacing alone, however, suffers from several disadvantages, for example, when the shoe laces or strap is drawn too tightly, the fastening system can cause pressure on the instep of the foot. Such localized pressure is uncomfortable to the wearer and can make it difficult for the shoe

to be worn for prolonged periods of time. Furthermore, while lacing allows the upper of the shoe to be adjustable to accommodate varying foot and ankle configurations, it does not mold the shoe to the contour of individual feet (Reebok international, 2014).

**Mobility issues**

Frydlewski, Waingarten, & Reeb (2014) also had similar conclusions as Neale's study (2012) that "Industrial applications of conventional fastening are often broken, shred, or become unreliable or even dangerous to users, during use, particularly during rough sports play or hard work activities". Accordingly, there is a need for an improved fastening device that provides an improved reliability, mobility and less user engagement. Further, there is also a need to improve a method of using a fastening device where the installation and application of a fastening device allows an adaptive use to a variety of alternative engagements. One typical closure system for an upper consists of an elongated opening having laces that may be used to pull together opposing edges of a portion of the elongated opening. Straps or buckles may be used in lieu of laces. Another typical closure system uses one or more elastic gores (or other elastic elements) that stretch during the insertion of the foot into the article of footwear. These closure systems require manipulation by a user, for example, by loosening or tightening the laces or by stretching the elastic, to provide for foot insertion, to provide for foot retention and/or to release the foot (Frydlewski, Waingarten, & Reeb, 2014). An example of another type of closure system is described in U.S. Pat. No. 6,189,239 (Gasparovic, Dieter, & Dalton, 2001), in which the shoe includes a forefoot portion and a rear portion that are joined by a flexure member in the midfoot region of the sole. The forefoot portion and the rear portion of the upper are separate assemblies.

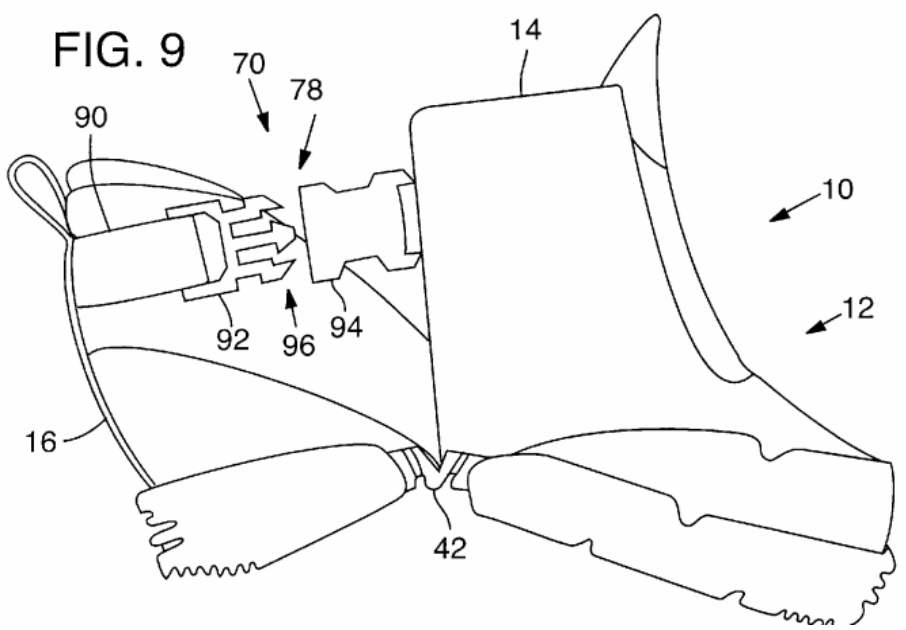



Figure 6: Patent invention (Gasparovic, Dieter, & Dalton, 2001)

In order to insert a foot into the shoe, the rear portion of the shoe is flexed downward relative to the forefoot portion, thereby providing an opening for the foot to slide into the forefoot portion. The rear portion of the shoe is then rotated back into alignment with the forefoot portion, thereby enclosing the heel of the foot. A strap is used to connect and secure the upper's heel portion to the upper's forefoot portion. This closure system has the same disadvantage as the above-described closure systems, as it too requires manipulation by a user. As an example, Figure 6 shows how the need for connecting and securing the strap across the rear and forefoot portions, in order to provide for foot insertion, foot retention and/or foot release, may involve too much user engagement and hence decrease mobility. “One of the specific guidelines to ensure if a protective shoe has proper fit, is to walk in the shoe and make sure it fits comfortably and adjusts to the foot, with little "break-in" time needed”, said John Klein, merchandising director of Red Wing Shoe Co (Nighswonger, 2000).

**Protection issues**

In addition to the correct footwear fit, the method of attachment such as zippers, buckles, straps and laces are important in ensuring that the foot remains firmly fixed in to the shoe. Any slippage of the foot within the shoe or breakage of, for example, functional straps may cause the wearer to slip or fall with resultant injury (Kyllo & Hudson, 2015).

While shoelaces substantially achieve their purpose of maintaining the tightness of a shoe, they have several drawbacks. For instance, when the laces are tied, the ends are exposed, generally hanging over the side of the shoe. The laces may be stepped on or become caught or entangled on another object. In this event, the lace will likely become untied, resulting in the loosening of the shoe. Additionally, the user may step on his own lace, causing to trip and possibly injure himself. Furthermore, a user may have a difficult time lacing his shoe to ensure the exposed portion of the lace on the left side and the exposed portion on the right side are of equal lengths. Still further, tying shoelaces can be frustrating for the user in achieving lengths in all exposed portions of the lace that will not become caught, tangled, or stepped on (Robinson, 2013 ).

A study by Nike (2012) found that the exposed recess for the spring or rigid element would tend to collect dirt, mud, or other debris, thereby undesirably increasing the weight of the footwear. These hardware items also may tend to catch on other objects on the ground, thereby causing safety issues. Although it is recognized that certain articles of footwear, such as clogs, mules, flip-flops, etc., have an opening for receiving the foot that is not enlarged/reduced, these articles of footwear are typically not securely held to the heel of the foot. Thus, these loosely-secured articles of footwear are not suitable for use in situations where the article of footwear must be reliably and securely attached to the foot. Additionally, for many of these loosely

secured articles of footwear, the upper does not include a heel portion. It would be desirable to provide a closure system for an article of footwear that would not require the use of hands to secure the article of footwear to a foot. Further it would be desirable to provide a closure system that overcomes the disadvantages discussed above (Nike, 2012).

**Summary**

Laced closure fasteners can cause difficulties and even danger to the wearer if they come undone during a sporting event. Clutch reel closures are best for users with limited mobility or restrictive circulation. The disadvantage of these known types resides in the fact that the angler is forced to impart a considerable number of turns to the knob to achieve, for example, the optimum fastening of the quarters (Baggio & Bortoli, 1989). Velcro closures loosen during wear and the shoe has to be discarded completely once the Velcro closure fails. This increases replacement cost (compared to laces) of an already expensive pair of waders. Buckle, straps or elastic require manipulation by a user, usually by stretching to provide for foot insertion/retention and/or to release the foot. Furthermore, exposed recess for the spring /rigid element / hardware items in conventional closure systems tend to collect dirt, mud, other debris, thereby increasing the weight of the footwear.

Ease of wear, ease of fastening, securing safe protection and limited effort to maintain a consist fit are major factors in selecting an appropriate fastening system in a fishing footwear. Accordingly, a need exists for an easy-to-use fastening system which securely fastens an article while adding minimal bulk, and which is easy to fasten and unfasten by the user. Thus, there is a desire and an unmet need to provide shoe closure devices that accomplish the closure mechanism of conventional tie laces in an effective and efficient manner.

CHAPTER III

# Methods/Procedures

## Purpose of the Study

This research aims to create a novel, utilitarian fastening concept in fishing footwear, where theoretical constructions and practical explorations of various forms of fastening are the core of the research. Efforts are made towards generating design solutions through an iterative design process to meet the needs of the consumers (improving fitting, protection and mobility).

## Objectives of the Study

The objectives of this study are to:

- Understand the functioning requirements of fishing footwear closure systems
- Identify design issues through user reviews and market research reports
- Find a conceptual design-solution through innovative ideations and expert selection
- Transform the product concept into a design-for-manufacturability prototype

## Design Process and Model

It is a widely held belief that modern design problems are more complicated than traditional ones that can be dealt with linear thinking or design-by-drawing. Unlike the conventional way of designing within the designer's mind, evolving techniques and design methods strive to externalize the design process and make it more open and manageable at a systematic level (Jones, 1970); (Van Shoor, 1989). According to Jones (1970), the differences between design methods can be viewed from three perspectives: creativity, rationality and strategy-control over the design process. The creativity perspective describes designing as working within a "black box", out of which the creative solutions come from within with all

possible input. In the “black box” method, the design process is described as unseen and mysterious. As for the perspective of rationality, each step in the process is explicable and rationalized by the designer, who is considered a “glass box”. The characteristics of the “glass box” method are that objectives, variables and criteria are established at first, analysis is completed in advance and evaluation is extensively logical then experimental, and strategies are decided in a sequential order. Both the “black box” and “glass box” way of design are deemed to enhance the chances of seeking optimal design solutions; however, weaknesses are that unknown knowledge remains to the designer for which he or she cannot simply rely on intuitive ideas or computerized logical analysis. Hence the final perspective of strategy-control is introduced where designers use external criteria and results of partial research to find short cuts in unknown domains, and further control and evaluate the design. External criteria used by designers could be impartial reviewers, who can bring in a different perspective or evaluate/validate the design outputs. Initial ideas are subsequently generated regarding how to approach the opportunity of developing an innovative fastener concept in fishing footwear. Next, an initial assessment serves to determine which ideas should be further pursued and proliferated to concepts, which are in turn re-evaluated. The same process of elaboration and evaluation is re-iterated until the final product is launched (delivered). The degree of elaboration refers to the level of detail of the evaluation input. It encompasses the parameters idea, sketch, concept, prototype and solution (Bullinger, Haller, & Moslein, 2009). Ideas are proposition of fastener designs, while sketches are visual depictions such as drawings, and concepts encompass descriptions that are more detailed. In general, they consist of answers regarding its functional design, often enriched by illustrations. Prototypes refer to virtual or physical proofs of concept. Solutions are fully

elaborated functional submissions; potential innovations are continuously reduced to the most promising ones throughout each stage of the innovation process (Cooper & De Brentani, 1984). Creativity, rationality and strategy-control perspectives adequately describe the design process but do not give specific details about how to respond to complex design problems. For the purpose of this study, a project based research was conducted based on the "iterative process cycle" (see Figure 1) in order to aid in engaging design process. The project based study will be an illustrative one to explore the design issues to improve fastening systems in fishing footwear is categorized into various research phases. Each step of the research process is elaborated and described in detail below (see Figure 7). The research was practice-led and exploratory in nature, and the knowledge was produced through creative practice with a novel concept.

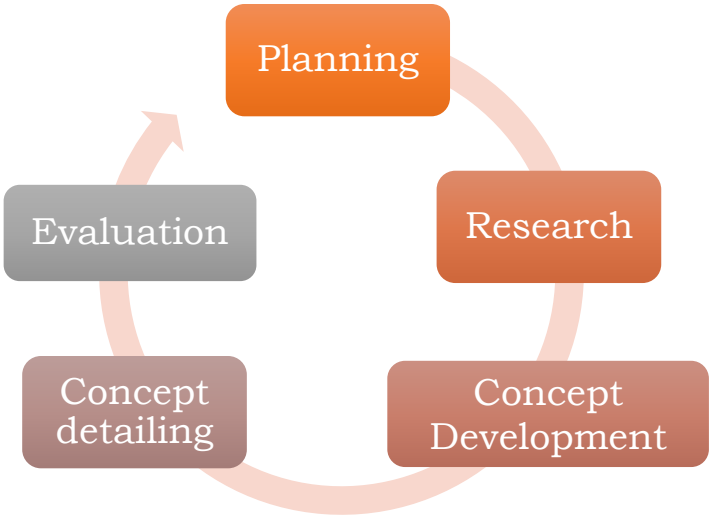



Figure 7: Phases of Project-based research

The project structure outlines the process that has been utilized throughout the project period. The structure describes the intention of each phase (goal/purpose), the activities that have been made and the output. The project structure describes the focus points of the project divided into the respective parts of the process.

The first stage of the project is planning phase, in which the goal is to resolve the problem into a basic statement that defines the product entity. The project is outlined and defined clearly - "To conceptualize a design solution in the form of a novel, utilitarian fastening concept in fishing footwear so that it offers optimum protection, fit and mobility to anglers". The goal of this stage is to explore various existing and possible fastening systems in fishing footwear through literature reviews and establish the design criteria, in terms of performance specific needs for closures in fishing footwear. A brief exploration on existing closure systems used in other functional and protective gears provided information about the design implications in generic sports and outdoor products. Furthermore, bringing a medical perspective to the existing functions of closure systems helped with need assessments of the user problems. Thereby, insights of the existing closure designs and its applications are gained to translate the acquired knowledge in making an informed design decision, ultimately leading to a final design solution (see Figure 8).

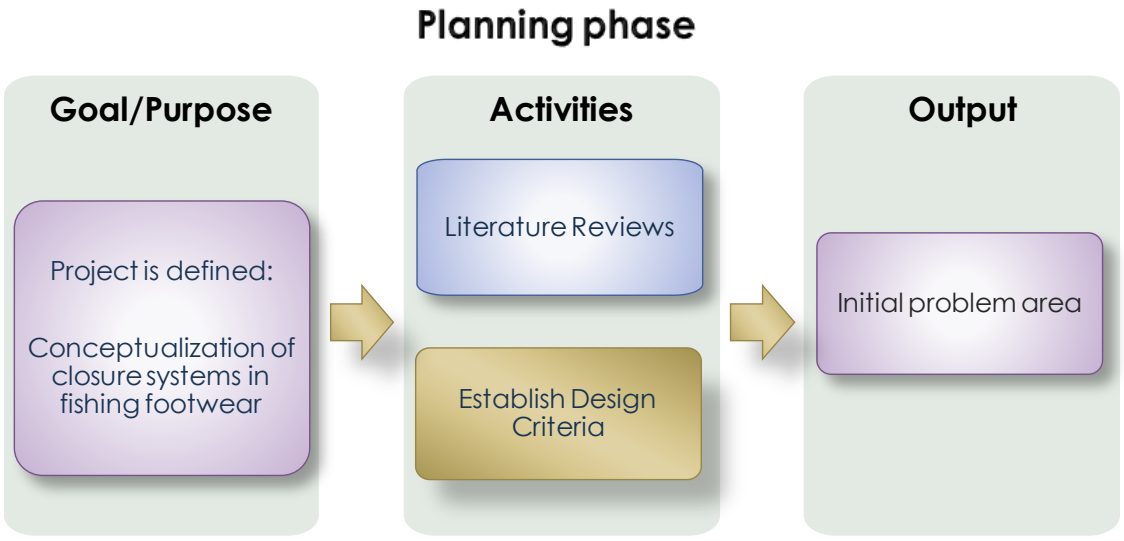



Figure 8: Stage 1- Planning phase

Next was the research phase, in which the user problems related to closure systems were assessed with respect to the utilitarian values based on three parameters of protection, fit and mobility requirements of fishing footwear. This assessment was achieved by assimilating market research reports and product reviews, interpreting the collected data for eliciting the needs properly. Popular websites for outdoor sports industry such as Amazon, Zappos, Cabela's and Bass Pro served as a good source for gathering product reviews. Also, different fishing blogs, where editors and customers write their stories/experiences of the product had been noted for better understanding of the shortcomings and advantages of existing closure systems. Lab reports and editor ratings, along-with customer ratings were also taken into consideration. The collected data, in the form of product reviews and study of literature was used to explore in more detail the spectrum of practice in fishing activity based applications. This phase helped form an all rounded understanding of performance requirements to be considered in later stages of concept development and evaluation. It gave a direction of work during brainstorming sessions and ideation phases aiming towards design conceptualization. Understanding derived through this practical assessment helped analyze the functioning of existing conventional closure systems. Assembling collected data in comparative tabular form was utilized in translating the acquired know-how to a conceptual solution for addressing needs of the users.

Typically, the first task on development projects is to discover, elicit, collect, define, and analyze requirements. Requirements cover various aspects of a product user needs, quality, implementation, etc. (Mitre, n.d.). Hence, in this study user needs were analyzed, transformed and integrated into fastening concepts as solutions to the identified needs. As a conclusion to the research phase, further clarification of central problem definition was elaborated, case studies on

best-matched (with respect to our criteria of protection, fit and mobility) selling products were documented and analyzed. (see Figure 9)

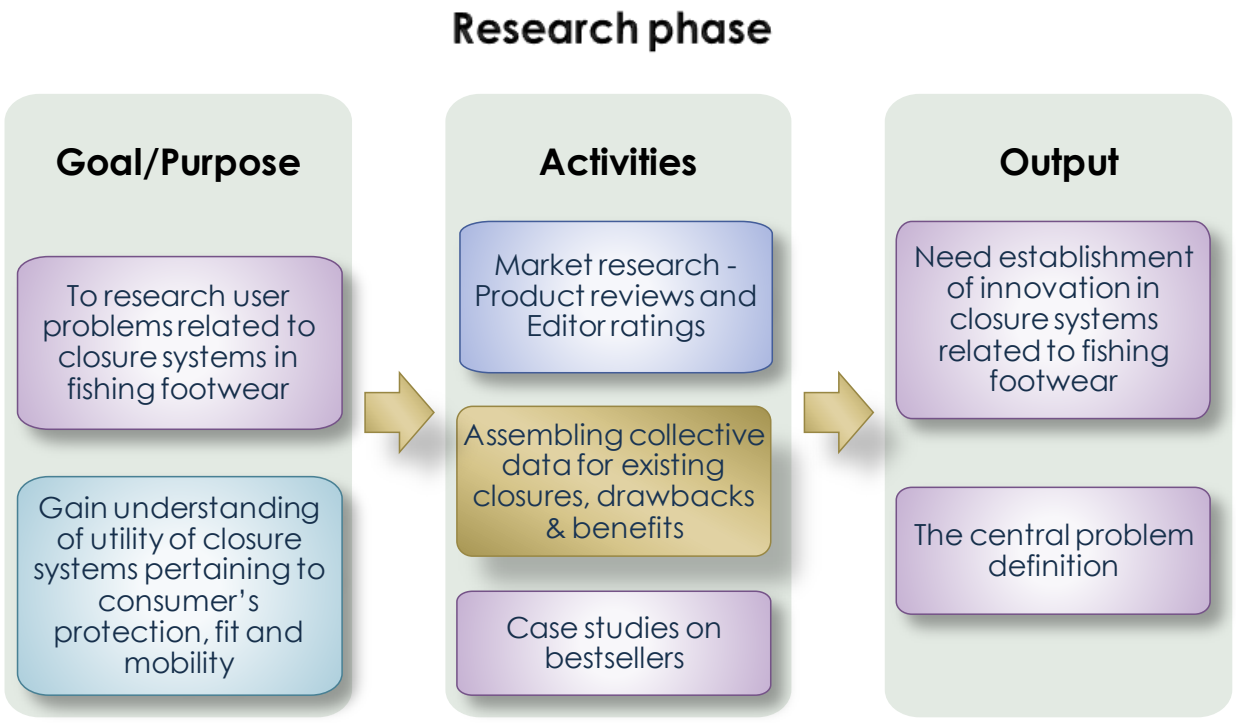



Figure 9: Stage 2 - Research Phase

The phase of Concept Development was the most crucial stage of this design research study. Based on the collected overview of knowledge and data, the ideas were conceptualized into forms of fastening elements of the footwear. Identified ideas were converted to implications for performance context relevant to the fishing footwear. Market research and studies were conducted at this point to understand how the concept will translate into a solution for the customer (Martin, 2014). A series of design alterations were created systematically in order to allow a structured analysis and assessment of the resulting visual concepts. The purpose of this step was idea screening, which was an initial assessment to weed out impractical ideas (Hart,

Hultink, Tzokas, & Commandeur, 2003). A list of important considerations was made in concept development that examined:

- Scope (possible materials, size of the trims)
- Schedule (time and activity milestones toward implementation)
- Fit (considering foot anatomy)
- Aesthetics, as it should look good as a fashion statement
- Patterns (providing coverage and protection)
- Mechanism (aiding easy adjustments and wear)

While many stages of the design development process benefit from unbounded creativity and divergent thinking during development stage of a concept, selection of that design is a useful process of narrowing a set of concept alternatives under consideration. Although concept selection is a convergent process, it is frequently iterative and may not produce a dominant concept immediately. It is essential to remember that a need might arise to generate new concepts, modify existing concepts, or undertake further research to proceed. Selection and evaluation are iterative processes that must be embedded in the development of the innovative product. In this study, similar kind of brainstorming and ideation activity yielded concept sketches (both ideation and technical drawings), which was then evaluated by the market experts (learned professionals from the footwear background) to shortlist the best among all the concepts, in terms of testing variables – fit, mobility and protection (see Figure 10). The first step in the judgment of feasibility during development and selection was to eliminate those concepts that are deemed "not feasible" under any conditions. Many times these judgments were based upon "gut feel" – however as trained designers, this "gut feel" was usually rooted in

technological knowledge. The “not feasible” concepts were not considered further but still remained recorded in the design report as reference. Sometimes a concept was deemed as “conditionally feasible”. This occurred when it was determined that a concept was workable if something else happened. This “something else” may have involved obtaining of currently unavailable information or the development of some other component. Conditionally feasible concepts required further determination and may have failed future evaluations such as technological readiness. The hardest concepts to evaluate were those where it was not immediately evident whether the idea was good or not, but the concept was “worth considering” (Cooper & De Brentani, 1984).

As a common practice, designers adopt some structured methods that can select a concept (Milton & Rodgers, 2011), including –

1. **CAD (Computer Aided Design) Models** — *used to evaluate a design and its perceived use during the different stages of the design process.*
2. **Matrix Evaluation** — *also known as the Pugh method, a quantitative technique used by designers to evaluate their concepts by ranking designs against set criteria.*

In this study, both these methods were used as a tool to guide iterative design processes, by structuring the way that concepts are identified, specified and evaluated (Burge, 2009). For utilizing the Pugh analysis, a mailed questionnaire was designed with list of questions comprising of four constructs, based on perceived utilitarian values of the designed CAD models. These constructs were categorized into Protection, Fit and Mobility and general question sections. Individual items in each construct were structured according to a 5-point rating scale. The questionnaire includes a detailed design technical sheet, illustrating all features and

dimensions for a clear idea to critique and respond to the questions. It is ascertained whether the respondents interpret the questions in the same way to establish reliability.

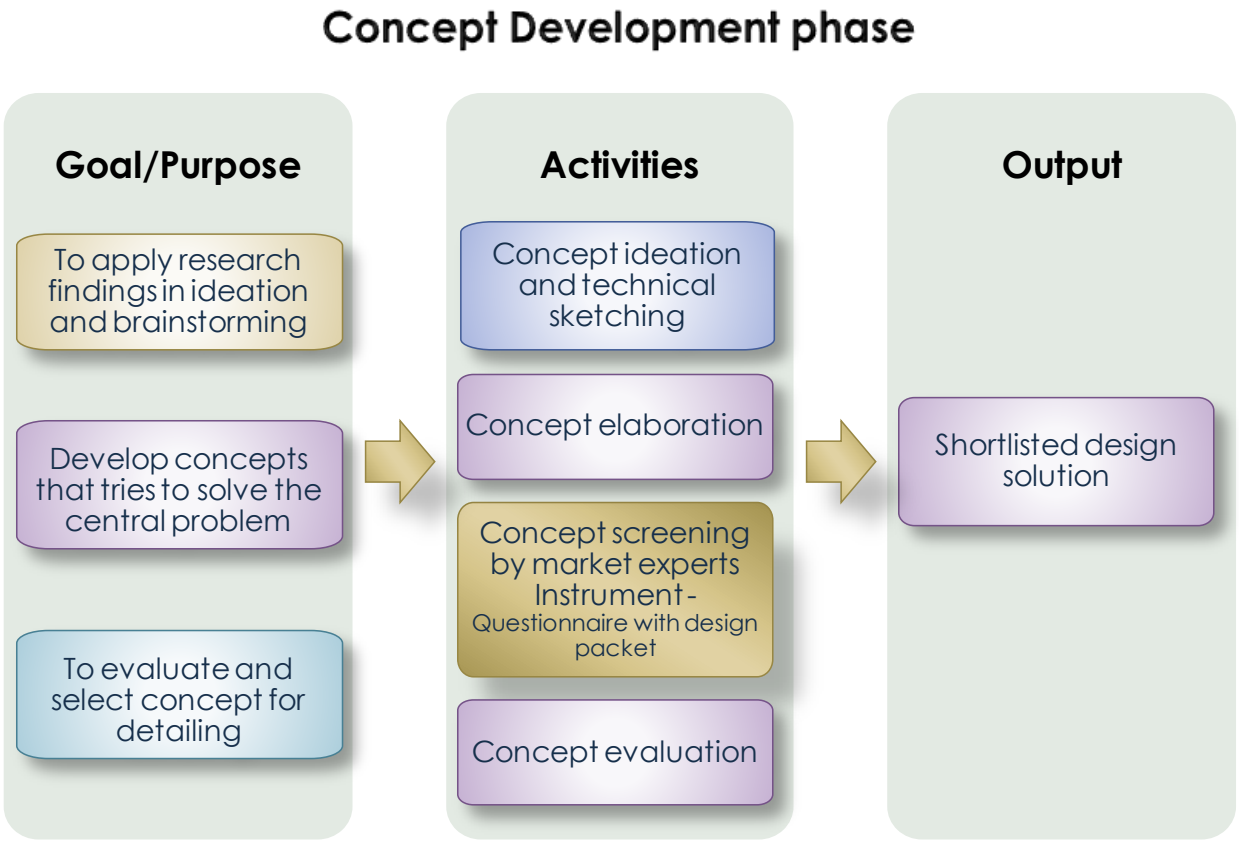



Figure 10: Stage 3 - Concept Development Stage

The collected data in the form of responses from the mailed questionnaire were analyzed. Outputs of the analysis were average mean score for meeting the overall performance requirements, from the questionnaires and any additional feedback sent electronically. The output was used to score the designs (according to matrix evaluation method) which helped identify which of the concept served the need best according to our chosen parameters. This step singled out one shortlisted design solution.

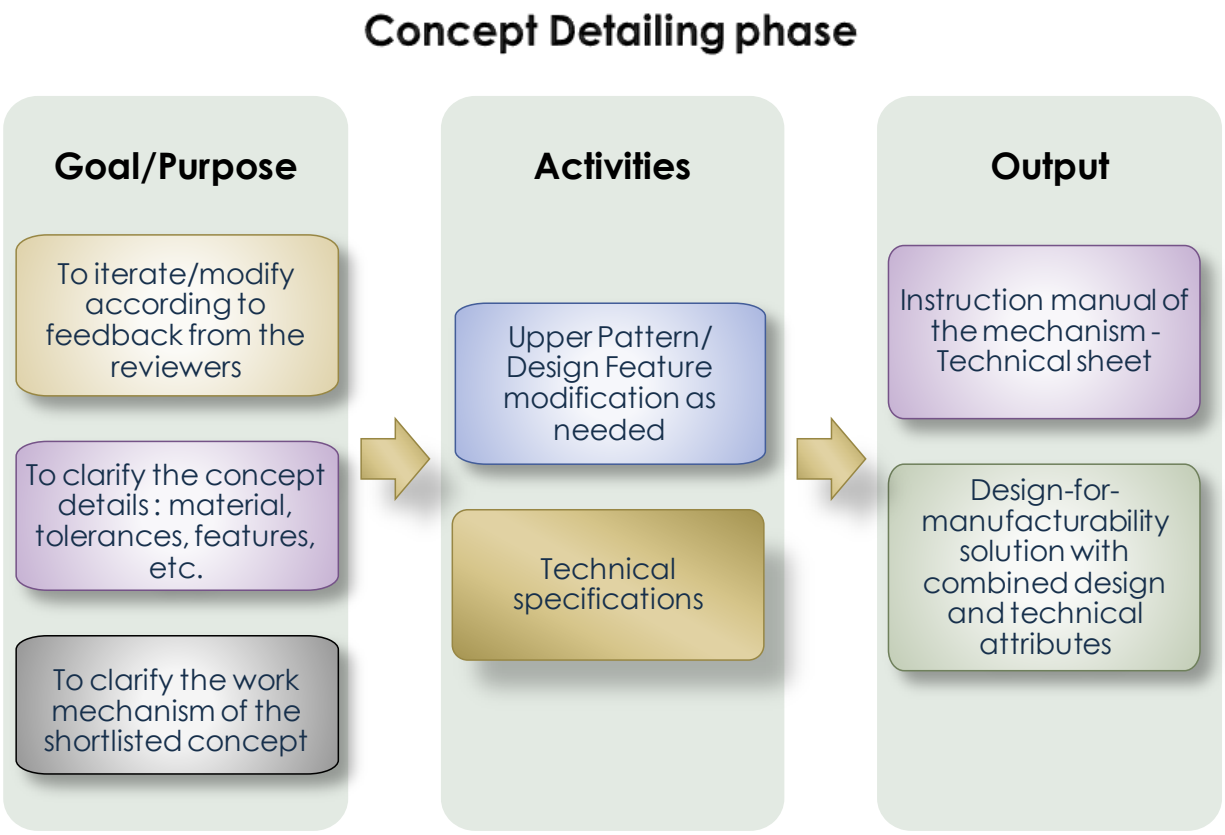



Figure 11: Stage 4 - Concept Detailing Phase

Concept detailing phase involved precisely revising and incorporating checkpoints and all other minute details into the product. It ensured the accomplishment of a complete product through enlistment of all technical specifications; pattern engineering of any upper/closure system modifications (see Figure 11). Technical specifications included specific details like, intended material to be used, aesthetics (color/texture/look) of the trim, instruction manual, etc. It provided an overview of all the tools/methods/process a designer had implemented to deliver the output of one's research in a clear, self-explanatory format. By documentation of individual components of the concept in a detailed manner, it became easier to find the traceability of the

design for future references. The detailed concept illustration and documentation was simplified at this step to make it a natural and integrated component of the overall design work.

The final stage of this project-based research was evaluation of the design solution in a graphical-concept form (as opposed to a physical footwear prototype). “Evaluation" was one of such core activities within the innovation process, which consisted of similar steps aimed at turning an idea into a product or service. The graphical design model ensured if the concept satisfied all utility parameters of fit, mobility and protection, as a fastening element in fishing footwear. The final concept was shared with the market experts for their evaluation with detailed illustrations including specifics and various visual perspectives of the shoe (see Figure 12). The instrument of final evaluation was a decision matrix, according to Pugh’s method (Burge, 2009). This particular evaluation needed highly detailed concept sketch and model with complete technical specification sheet and additional justification from design standpoint of the concept. Data analysis of the validation method yielded approval rating of the final concept for meeting all the performance requirements. This was an effective technique to utilize before physical prototype manufacturing, as it saves valuable resources such as time and revenues(Milgrom & Roberts, 1990).

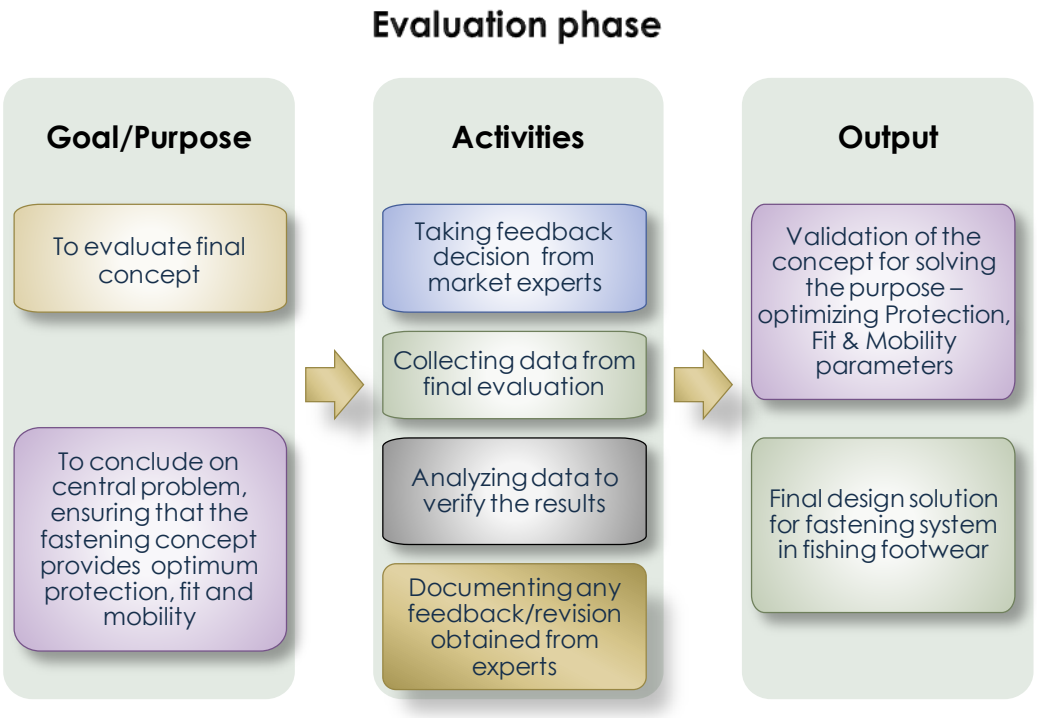



Figure 12: Stage 5 - Evaluation Phase

**Use of Findings**

Our investigation identified a number of important considerations for the designing and development process of fastening systems in fishing footwear. The graphical test concepts which utilize findings from this iterative design process can be implemented in manufacturing to produce a small order for market trial. This will examine how an iterative design process can integrate both aesthetics and functionality to provide a design solution. The results from this study could be applied to other functional, fashion and sports products in general, as bags, belts, jackets and other gears. That has been shown as an introductory application in other outdoor gears for emphasizing the utility of the evolved concept. Therefore, the findings of this study have provided a basis from which further design investigation of this concept's extended application could be studied.

# CHAPTER IV

## Planning and Research

This chapter details the preliminary planning and research phases of design as highlighted in the previous chapter(s), prior to concept development and detailing phases of design. The following section starts with the planning phase, which provides a summary of the literature review in the previous chapter while exploring the closure needs specific to fishing footwear. This involves establishment of design criteria such as fit, protection, water/corrosion resistance, etc., which have been discussed herein. The planning section is followed by a detailed research phase section which covers elaborate market reviews, hands-on test findings, analysis of various shoe closures and existing technologies, including shoelace technology, athletic shoelace specialized systems, pertaining to current study.

### Planning Phase (Stage I)

The planning phase documents the initial work done, including preliminary research and project framing. The planning phase is used as a tool to control the process and understand the project's limitations and requirements.

The literature review clearly outlines that laced closure fasteners can cause difficulties and even danger to the wearer if they come undone during a sporting event. Among the dangers are slippages of the associated shoe relative to the foot of the wearer and associated instability as well as the tripping danger in the event that the untied lace is stepped on or becomes tangled. Accordingly, a need exists for an easy-to-use fastening system which securely fastens an article while adding minimal bulk, and which is easy to fasten and unfasten by the user. Thus there is a

desire and an unmet need to provide shoe closure devices that accomplish the closure mechanism of conventional tie laces in an effective and efficient manner.

***Establishment of Design Criteria***

An efficient fastening system in wading shoes will always provide the necessary safety, comfort, fit, stability and maneuverability. Based on the literature review and product reviews, below are some important criteria for exploring an effective fastener in fishing footwear.

**Great fit and support:** Having a good fit and proper support will not only provide excellent traction & stability on the water but it will save the angler's ankle on the rocky river. Without proper fit, there are risks of twisting the ankle even while wearing an excellent wading boot. A pair of shoes with comfortable fit will provide the best balance on slippery surfaces and rocks along the beach shores. Shoe closures which provide a neat fit manages to withstand the test of time; especially with day-long fishing activities in different terrains.

**Superior Protection:** Fishing shoes should also stick to the feet like glue, so they do not come off when you wade through sticky mud. Therefore, the fastening system should be securely locking the foot in its place to optimize performance in varying conditions in and out of water. Shoe closure should be specially designed to prevent any sand, dirt, gravel or debris from getting inside.

**Water and corrosion resistant:** Water repellent synthetic materials are the norm for good quality fishing. The fastening hardware, like buckles and lace locks should be resistant to corrode after exposure to the salt from the sea. Fasteners should be water repellant and resistant to mold and other invasive species in the river. For example, cotton is not an option, because it tends to absorb a lot of water and it also breaks with the constant pressure applied on the laces

during fishing. Nylon and polypropylene are a much better idea because they are resistant to water and can also handle a lot of pressure. This way, an angler does not have to drag his/her boots filled with water for the entire day.

**Easy maneuverability:** Shoe closures in fishing footwear must balance motion control; everything from limiting excessive foot motion to allowing feet to move as nature intended. Providing easy adjustment and a quick on/off transition is also another requirement for anglers who are moving from different terrains like slippery dock to the bank or hiking moderate to long distances to reach their fishing destination.

Anglers need fishing gear (shoes) that is functional, innovative and can withstand whatever abuse they put it through. A shoe closure that is designed to meet the performance needs of anglers is gear which can be counted on. As certain important characteristics have been identified in fishing footwear above and it's fastening requirements, a better exploration and comparison of existing fasteners in the market could be done. This will help identifying the niche with an innovative design solution, which conforms to the functional needs of fishing shoes.

**Research Phase (Stage II)**

A brief review of existing fasteners and its function in fishing footwear, attributing to the basic material characteristics has been done that will help make an informed decision about performance specification of closure designs. Customer needs can be identified through extensive market studies, observing similar products in use and reviews from manufacturers and purchasers (Martin, 2014).

***Existing Shoelace and Fastener Materials***

Concrete, practical examples are identified in order to present knowledge taken from real solutions that will help provide a better understanding of the type of solution that is being created in this project. Elastic (bungee-like cord) lacing material may be preferred by anglers who want a softer and looser feel and may be beneficial for enthusiasts with injuries. The extra flexibility expands and contracts with the foot and may aid healing and reduce pain and discomfort. Shoes with elastic laces may be easy to slip on and off, but they may not provide as much stability and support.

Non elastic (cotton, braided, or nylon) shoelace material is recommended for outdoor enthusiasts with healthy feet who prefer a snug and secure feel to their specialized shoes. A combination of outer nylon with inner elastic makes a “finger-trap” system, providing both strength and flexibility. Pull on closures offer the greatest degree of convenience, and the lowest possible weight, but the least customizable fit. They are often found on water shoes, or barefoot-style minimal footwear.

Velcro straps are sometimes used in place of shoelaces and may be useful for waders who may have a difficult time lacing shoes; however, Velcro straps will not provide as much athletic

foot support as tie-lacing. For those anglers with arthritis, mobility issues, or for novice anglers who haven't learned to tie shoes yet, Velcro offers a huge degree of independence. Velcro closures are not the most secure, so they are an uncommon choice for anglers of average mobility.

The zippers can only withstand the same wear and tear as the rest of the shoe in harsh marine environments, if it is made up of heavy duty material. Zip closures are well-suited for anglers with mobility issues, and are sometimes found on ice fishing boots. Buckles should be protected against corrosion and enameled several times to be used in harsh marine environment.

Shapes of sports shoelaces can also vary, which may affect the ease of tying and tightness of the knot. Different shapes of laces include traditional flat, thick round "cord-like," oval, and even ribbed for additional knot strength.

***Shoelace Technology***

Shoe lacing technologies may be helpful to certain athletes. Many unforeseen problems can occur during a sporting event, including athletic shoes that come untied. Untied shoelaces can be both a frustrating and a dangerous problem and has prompted the development of advanced lacing systems and lacing materials.

Shoelace-locking systems can keep shoelaces tied and can also affect the ability to quickly slip a shoe on or off the foot. Quick shoe application and secure shoelace locking can be important in sports such as triathlon and adventure races, in which a quick transition time (T2) from the land to water can be critical. Several common shoelace systems and materials geared to assist improved shoe-fitting through lacing are presented.

***Athletic Shoelace Specialized Systems***

Athletic shoelaces becoming untied during fishing activity can be dangerous as well as harmful to performance. In the past, athletes who have had problems with shoelaces untimely becoming untied during training or competition found it helpful to cinch the shoelaces in a double or triple knot; however, these tend to loosen and need to be re-tied. Another technique used to prevent fishing shoes from becoming untied includes wrapping athletic tape around the outside of the shoes and laces.

Newer patented lace-locking systems such as Lock Laces (Lock Laces, 2016), Speedlaces (Speedlaces, 2016), Xtenex (Xtenex, 2016), Tyless (Tyless, 2016), Squeezums (Squeezums, 2016) and Yankz (Yankz, 2016) use specialty shoelace-locking designs and materials to help prevent loosening and to improve performance and comfort. Once these lacing systems are fit to the shoe, they need minimal readjusting, and they eliminate floppy, loopy laces. However, one potential concern with these lacing systems remains slippage at the lace–lock interface.

Lock laces are a patented elastic lacing system that features especially designer elastic laces combined with a spring-activated locking device. The lace uses curve tips to allow the lace to pass more easily through the eyelet configurations in fishing shoes. The laces are made with water-resistant banded, multi-strands of elastic/bungee. The lock is a slideable spring-activated device made from a strong, durable, and lightweight plastic which hold the laces in place. The tension springs are made from a metal alloy, resistant to rust and corrosion. Lock laces use a traditional lacing scheme with specialized laces and a locking mechanism in place of a traditional knot. Speedlaces replace ordinary laces and provide added support and stability, instant tension adjustment, and eliminate the need to re-tie laces again. Xtenex laces incorporate a novel knotted-lace design which does not require any lace tying or extra hardware; these laces were

worn by the Olympic gold and silver medalists in the 2008 Olympic Triathlon competition. Tyless and Squeezums incorporate a plastic mechanism which allows quick cinching of the laces without the need to tie a knot.

***Markets Review of Fishing and Related Footwear***

Market reviews of popular fishing shoes and boots can become the foundation for creating the fastening system designs. A different fisherman has different criteria to choose their best fishing shoes. There are other conditions like environment and nature to influence the decision. From slinging baits from the bow of a bass boat, stalking spooky permit and bonefish across saltwater flats, or hopping into and out of a kayak all day, as an angler portage from one remote trout lake to the next, there is a shoe for nearly every angling endeavor.

Any individual who engages in fishing sports will need to determine what their needs are. Since water shoes (Fishing shoes) work well out of the water, they can be used for short and moderate length hikes in terrain that requires many stream crossings or wading through water (Big Sky Fishing, n.d.). The excellent traction and design allows them to work well out of the water, for which it can be easily converted into a hiking shoe. Water shoes are an ideal footwear choice for fishing trips because they facilitate both hiking and floating properly. It is generally found that fishing gear is designed specifically for both fishing and hiking purposes, which is a must-have thing while hiking or fly fishing on rivers / rocky rivers. Moreover, there is hardly any difference with respect to the function and features of fastening system, when it comes to fishing and hiking footwear. Both of the outdoor gears are tested, designed and evaluated, based on same harsh environment conditions of muddy trails, gravel/debris, wet, slippery surfaces. Perhaps, the only different attribute to hiking shoes evaluation is weight-bearing capacity, because of the

heavy bag-packs of the hikers. The requirement of fishing footwear closure in the weight sustenance regard is far less than what is required for hiking purpose. Thus, it is safer to assume that shoe closure pertaining to hiking category is perfectly suitable for fishing footwear. Furthermore, it is interesting to consider broadening the category of fishing and hiking shoes/boots, so that more reviews can be collected to analyze the functionality of existing closures. The list of 10 best wading boots for Fly Fishing & Hiking (Afsar, 2015) is shown in Table 1. Please note that the evaluation rating (based on numbers out of a maximum of 5.0) is based on totality of the product like good comfort, better grip for grasses & rocky rivers, good stability, better drainage and a cost efficient price.

Table 1: 10 Best Wading Boots for Fly Fishing & Hiking

| Model | Closure | Editor Rating |
|---|---|---|
| Caddis Men's Wading Shoe | Laces | 4.5 |
| Redington Skagit River Wading Boot | Laces | 4.9 |
| Redington Prowler Premier Wading Boot | Laces | 4.5 |
| K-5 Bomber Wading Boot | Cord laces with rolling guides and locking cleats | 4.6 |
| Redington Palix | Lacing with moulded, non-corrosive metal hardware | 4.4 |
| Allen Company Blue River Wading Boot | Brass D-ring speed lacing system | 4.4 |
| Frogg Toggs Rubber Outsole Wading Shoe | Brass D-ring speed lacing system | 4.5 |
| Adamsbuilt Gunnison River | Web Lacing System | 4.6 |

| Model | Closure | Editor Rating |
|---|---|---|
| Wading Boot | | |
| Orvis Encounter Wading Boot | Laces | 4.8 |
| Korkers BuckSkin Wading Boot | Laces | 4.8 |

During the review process, it was realized that it was not enough to merely know if the reviewer liked or disliked the product. It is aimed at knowing how they stack up against all the other top products out there, and why one product may be better than another. Best gear reviews were those that objectively compare and contrast. Outdoor Gear Lab Review Editors put the products through detailed side-by-side tests, both in the lab and in the field, and score each product across a range of weighted categories (Chris McNamara, 2015). Their review process starts with selection: they look at hundreds of products to determine the top contenders in each category. The top contenders are bought from the market for detailed hands-on testing. A set of objective lab tests for each category is developed to provide a fair basis for scoring, which helps in quantifying important differences between competing products. In addition, each product is put through a set of real world field tests where it is used and abused against each product to see how it holds up to its competition. Outdoor Gear Labs tested and compared five of the top-rated models to find out the pros and cons of each top-rated model in fishing and hiking category. Fishing-cum-hiking shoes are tested in all conditions, from dry and dusty trails to rain, snow, gravel and mud. Expert testers hiked in the desert and to snowy mountain tops; on well-traveled trails and way, way off trail. Each boot's construction, devised tests, logged thousands of miles is scrutinized, and ranked each one's performance in comfort, traction, stability, versatility, weight,

water resistance, support, and durability. There are three award categories for the comparative review of fishing shoe and fishing boots. **The Editors' Choice** award goes to those products that are believed to be the very best overall. **The Best Buy** award goes to quality products that offer the most valuable according to the price. **The Top Pick** award goes to those products that stand out for specific applications, and the review will explain the details of why and what for.

***Analysis and Hands-on Test Findings***

*Best overall fishing-hiking shoes related to closure*

Keen Targhee 2 is ranked second in this category and is also the Best Buy Award winner (see Table 2). According to the review, this model's four eyelet lacing system is considered top notch. Three widely-spaced lower webbing eyelets lace the boot over the fore and midfoot. This wide spacing allows folks with narrower feet to snug the upper down. The upper webbing eyelet extends down and around the heel of the shoe, creating the ability to cinch the heel down in the heel cup (see Figure 13).

Figure 13: Keen Targhee 2

Many outdoor enthusiasts praise this feature. With a little experimenting, the forefoot can be laced loosely for comfort. One of the customer (2015) reported, “Only caveat is I had to use heel lock lacing on the uppermost eyelets, and a surgeon's knot on the next-to-bottom eyelets, to avoid heel slip and toe impacts in the very generous toebox - your mileage may vary”. Probably, the comfortable lacing system falls short in providing security. It is also reported that the webbing lacing eyelets wear out easily, especially in harsh conditions.

Table 2: Test Results and Ratings of Best Overall fishing-hiking shoes for men (Lampley, 2015)

| Rank | #1 | #2 | #3 | #4 | #5 |
|---|---|---|---|---|---|
| Product |  |  |  |  |  |
| | The North Face Ultra 109 GTX | Keen Targhee 2 | Vasque Juxt | La Sportiva FC ECO 2.0 | The North Face Hedgehog Hike GTX |
| Awards | Editors' Choice | Best Buy | | Top Pick | |
| Price | Varies from $120 - $135 online | $125 List \| $125 online | Varies from $82 - $110 online | Varies from $135 - $150 online | $140 List |
| Overall Score | 85 | 81 | 80 | 80 | 77 |
| Star Rating | ★★★★★ | ★★★★★ | ★★★★☆ | ★★★★☆ | ★★★★☆ |
| Pros | Great do-everything shoe, slim toe profile, excellent all-around traction, good torsional stability | Great traction and comfort, great foot support, extra toe protection, secure lacing | Lightweight, breathable, great dry traction, inexpensive | Very durable, great foot support, snug fit | Lightweight, good foot support, all-around traction |
| Cons | Not the most durable | Webbing lace eyes can wear, a bit wide for narrow feet | Not waterproof | Heavy and stiff | Durability concerns, break-in period required |
| **Ratings by Category** | **The North Face Ultra 109 GTX** | **Keen Targhee 2** | **Vasque Juxt** | **La Sportiva FC ECO 2.0** | **The North Face Hedgehog Hike GTX** |
| Comfort - 25% | 10 | 8 | 10 | 8 | 8 |
| Weight - 25% | 7 | 9 | 5 | 7 | 7 |
| Support - 15% | 9 | 9 | 9 | 8 | 7 |
| Traction - 15% | 7 | 7 | 10 | 9 | 8 |
| Versatility - 10% | 9 | 8 | 7 | 8 | 9 |
| Water Resistance - 5% | 8 | 7 | 6 | 8 | 7 |
| Durability - 5% | 7 | 6 | 7 | 8 | 6 |
| **Specs** | **The North Face Ultra 109 GTX** | **Keen Targhee 2** | **Vasque Juxt** | **La Sportiva FC ECO 2.0** | **The North Face Hedgehog Hike GTX** |
| Weight of pair (lbs) Size 12 | 2.3 | 2.3 | 2.1 | 2.5 | 2.2 |
| Upper | Mesh and PU-coated leather | Nubuck and textile | Suede leather | Nubuck Leather/ recycled Nylon Mesh/ Uretech | Full-grain leather, textile mesh, synthetic overlays |
| Waterproof Lining | GORE-TEX Extended Comfort | KEEN.DRY waterproof breathable | None | GORE-TEX Extended Comfort Footwear | GORE-TEX |

**The Hedgehog** is **ranked fifth** in overall category and has an impediment in slow break-in period, which refers to “difficulty in getting the foot inside” (see Table 2). It is a big drawback, especially when the anglers need quick adjustments on the run/during the activity. The lacing

Figure 14: The Hedgehog

system used on the Hedgehog is mostly traditional and it could be anticipated that break-in time could be reduced significantly with an easy and quick fastening system.

Anglers with concerns about twisted ankles, or previous ankle injuries, will want a stable, supportive boot. Fishing-cum hiking boots are generally more durable, and provide better foot and ankle protection on rough, rocky trails. If you hike on slippery trails with lots of roots, boots are the ticket. They will also keep our feet dry and comfortable when the trails are inches deep in mud or slush. Travel off-trail in rough terrain demands boots, and in areas where snakes and other critters lurk, footwear that covers the ankle provides additional peace of mind. The higher cut collar does a better job keeping pebbles and sticks out, and provides the height for a waterproof liner to keep you dry. Thereby, apart from fishing shoes, it will be also interesting to explore closure system in popular fishing boots as well (see Table 3).

Table 3: Test Results and Ratings of Best Overall Men's fishing-hiking Boots (Lampley, 2015)

| Rank | #1 | #2 | #3 | #4 | #5 |
|---|---|---|---|---|---|
| Product |  Vasque St. Elias GTX |  Salomon Quest 4D II GTX |  Keen Targhee II Mid |  La Sportiva FC Eco 3.0 |  Lowa Renegade GTX Mid |
| Awards | Editors' Choice | Top Pick | Best Buy | | |
| Price | Varies from $154 - $200 online | Varies from $164 - $240 online | $135 List \| $135 online | Varies from $122 - $175 online | Varies from $172 - $230 online |
| Pros | Comfortable, stable, great ankle collar, minimal break-in time | Comfortable out of the box, makes you want to move fast, great stability and support | Secure lacing, extra toe protection, great traction, and out-of-the-box comfort | Light, comfortable, good sole, large toe box | Comfortable collar, good muddy traction, seamless Gore-Tex liner |
| Cons | Minor durability issues, permeable leather needs treatment | Lots of seams to wear out, a little too burly and aggressive for casual hiking | Lace eyes wear out | Basic lacing system, forefoot mesh chilly in cold weather | Laces coming loose, lots of upper seams |
| Overall Score | 85 | 81 | 80 | 80 | 77 |
| Star Rating | ★★★★★ | ★★★★★ | ★★★★☆ | ★★★★☆ | ★★★★☆ |
| Comfort - 25% | 10 | 8 | 10 | 8 | 8 |
| Stability - 20% | 7 | 9 | 5 | 7 | 7 |
| Traction - 15% | 9 | 9 | 9 | 8 | 7 |
| Weight - 15% | 7 | 7 | 10 | 9 | 8 |
| Water Resistance - 15% | 9 | 8 | 7 | 8 | 9 |
| Duarability - 10 % | 8 | 7 | 6 | 8 | 7 |
| **Specs** | **Vasque St. Elias GTX** | **Salomon Quest 4D II GTX** | **Keen Targhee II Mid** | **La Sportiva FC Eco 3.0** | **Lowa Renegade GTX Mid** |
| Weight of pair (lbs) size 12 | 3.5 | 3.5 | 2.5 | 2.6 | 3 |
| Boot Type | Midweight Hiker | Midweight Hiker | Lightweight Hiker | Lightweight Hiker | Midweight Hiker |
| Waterproof Lining | Gore-Tex | Gore-Tex Performance Comfort Footwear | KEEN.DRY waterproof breathable membrane | Gore-Tex | Waterproof, breathable GORE-TEX |

*Best overall fishing-hiking boots related to shoe closure*

Three main attributes are noted when considering comfort: how the foot feels in the foot bed, how the ankle collar feels, and how the lacing system works and how well the boot breathes, keeping the wearer cool and dry. The number and type of lacing eyelets and whether there's any slippage is noted in the wear tests.

The **Salomon Quest 4D II GTX** is awarded top pick and ranks 2nd in overalls (see Table 3). This model's lacing system is perhaps the best according to the field tests. Four lower eyelets

Figure 15: Salomon Quest 4D II GTX

allow the anglers to custom fit the forefoot of the lower boot, which is very flexible. Folks with both a wide forefoot and a narrow forefoot praise the fit of the shoe. The middle eyelet has the best positive lock as tested, and its large radius makes it easy to use. Two upper eyelets complete the lacing system. The design of these upper eyelets is top notch; they capture the laces is such a way that having them pop loose is out of the question, but the laces can still slide freely as our ankle flexes. So, free loose ends of the laces remain to be a problem.

The **Keen Targhee II, ranked third** in the table below (see Table 3) is rated well for its secure lacing (see Figure 16). The lacing system is made up of three lower, one in the middle,

and one upper locking eyelet. The middle webbing eyelet continues down and around the heel of the boot, providing the ability to cinch your heel down.

Figure 16: Keen Targhee II

The upper eyelet provides a positive lock on the laces, so even if your bow comes untied, the lacing system does not loosen. One of the lower three eyelets that could be tied loosely, and one lace for the upper two eyelets offers a tight fit for the heel and ankle. The Targhee's innovative middle lacing eyelet is a game changing innovation for customizing the fit. On the other hand, it has a major flaw in potential breakage of the laces under harsh conditions and rough usage. It is reported that the fabric eyelets wears out and breaks, rendering the boot unusable.

**La Sportiva FC Eco 3.0** is **ranked fourth** and has a disadvantage of having a basic

Figure 17: La Sportiva FC (4th ranked overalls)

lacing system for a high performance shoe (see Figure 18). Rather than traditional eyelets on the forefoot, the laces pass through four webbing loops, and then a single hook eyelet up on the ankle collar. This is the simplest lacing system out of the tested products, and doesn't provide much flexibility in adjusting the fit.

**The Lowa Renegade GTX Mid** is **ranked fifth** in overall category. Even though this boot earned great scores across our metrics, its lacing system is disappointing for the field testers and consumers (see Figure 19). Four lower eyelets, one middle lock, and two upper hook eyelets comprise the lacing system. The middle locking eyelet is small and hard to get at, and doesn't

Figure 18: Lowa Renegade GTX Mid, ranked 5th in overalls

lock tight on the factory laces. Additionally, the laces popped right out of the top hook eyelets more than once when walking steeply up into the rocks. These closures falls short in ease of use and secure locking features.

As a conclusion to the market review conducted above, it was found that conventional laced systems are still the most applied closures in top-rated models. To adhere to broad range of angler activity, innovation in lacing styles were predominant, as opposed to the fastening style itself. While it served the purpose for many customers towards an overall shoe model, the closure needs were not fully addressed for every angler. As reported by customers and editors, identified

functional needs of a shoe closure device in fishing sports were secure locking, ease of use, flexibility in adjustments, customized fit, sustaining rough and harsh environmental conditions.

***Review and Analysis of Shoe Closure Systems***

As a summation of market reviews of top rated products in fishing footwear from various categories, it is found that the most conventional closure in action today is laced system. There are only innovations in varied ways of lacing techniques to accommodate even pressure distribution. So, it was necessary to look at other forms of closures in different products, outside of fishing footwear category. With a sound understanding of the needs, functioning requirements and drawback of traditional closures in fishing footwear, other fastening systems could be implemented in the fishing gear to provide innovative solutions. Popular forms of different shoe closures found in other footwear categories and utilitarian products including bag-packs, clothes, helmets, luggage mount, belts and diabetic and medical products are laces, Velcro, zipper, buckle, clutch reel system and magnetic systems.

Shoes with Velcro closures instead of laces are a great aid for those with arthritic or otherwise


Figure 19: Zubits magnetic closure

challenged hands, or folks in a hurry to put it on and start their activity. But magnetic shoe closures, like Zubits are for those who love lace-up shoes, except for the laces. Just unlace the

shoe's top three eyelet rows and re-lace through the holes on both sides of the rectangular plastic Zubits casing, with the magnetic inner edges connected. Then twist the two sides of the rectangle in opposite directions to pull them apart (see Figure 20). Step into your shoes, bring the two very strong magnetic halves together and it is locked securely. The downside is that the process is a little more complicated than that, requiring some trial-and-error adjustments based on walking around, bending the feet and then snipping off excess shoelace ends. Zubits are not recommended for physically challenged individuals, as it may be too difficult to maneuver and has issues with mobility (Dash, 2016).


Figure 20: Clutch reel technology closure in ACE™ Brand Elbow Strap

There are clutch reel technology closures introduced in medical products, which offers customized fit with just turning the dials to tighten. People complain that the single dial boots have pressure points and it only control the pressure in positioned area (see Figure 21). This may cause fit and mobility issues, as the pressure distribution across the feet remain uneven.

Closures from various application areas, mostly in footwear, have different types of requirements and hence different features were investigated.

Table 4: Comparison between different shoe closures

| Based on **Consumer & Literature reviews** | **Comparison Between Different Shoe Closures** | | | |
|---|---|---|---|---|
| | **ACCESSORIES** | **PROS** | **CONS** | **POPULAR PRODUCTS** |
| **LACES, ELASTIC & CORDS** |  | • Reliable and good support<br>• Offers more contact points<br>• Highly customized and fine-tuned fit<br>• Easily replaceable | • Uneven pressure distribution if incorrectly done<br>• Loose ends/untying poses risk of injury<br>• No adjustments on the run<br>• May get messy when wet | • Aerodynamics & lighter shoes<br>• Kids shoes for promoting cognitive skills |
| **VELCRO** |  | • Simple & quick method<br>• Needs less forces to close, more while opening<br>• Ripping sound makes opening action noticeable<br>• High Shear strength | • Material tolerance up to 280 F, tends to break down/melt if brought into contact with heated surface<br>• May not offer water protection | • Insulation blankets<br>• Shoes & clothes<br>• Utility items<br>• Aerospace industry- food pouches & marine gear bag |
| **ZIPPER** |  | • No constant adjustments; assured same fit every time<br>• Fail-safe, 2 failures per 1000 boots sold(Dave, 2012)<br>• Easier to close even with glove | • Needs to be perfectly aligned for smooth closure<br>• Difficult to use on the run, compared to Velcro<br>• May not offer water protection | • Tactical Boots<br>• Utility Products like bags and clothing |

| Based on **Consumer & Literature reviews** | **Comparison Between Different Shoe Closures Continued...** | | | |
|---|---|---|---|---|
| | **ACCESSORIES** | **PROS** | **CONS** | **POPULAR PRODUCTS** |
| **BUCKLE** |  | • Sturdy and secure<br>• Suitable for extreme temperatures<br>• Waterproof<br>• Easy on & off<br>• Resistant to Dirt/Debris/other micro-organisms in water | • No provision for fit adjustments except for Cam buckles<br>• Skin pinching if not backed up with proper lining | • Mountain hardware<br>• Utility Products like bags, clothing<br>• Heavy duty work boots<br>• Other protective gears |
| **CLUTCH REEL SYSTEM** |  | • Secure<br>• Comfortable fit<br>• Waterproof<br>• Easy and on-the-fly adjustments<br>• Suitable for extreme temperatures<br>• Reduction in shear force | • Replacement needs re-installing dials<br>• Only controls pressure in its positioned area | • Helmets<br>• Bags<br>• Diabetic and Medical products including shoes |
| **MAGNETIC SYSTEMS** |  | • Fast, simple and easy method<br>• Quick on-the-fly adjustments<br>• Great for arthritic wearer | • Some trial and error adjustments based on walking around, bending your feet and then snipping off excess shoelace ends | • Helmets<br>• Footwear<br>• Bag packs<br>• Motorcycle luggage mount<br>• Belt buckles |

Based on these features, it was found that different closure mechanisms can be utilized in fishing footwear pertaining to its suitability and utilitarian needs. Combined market reviews with study of literature reflected a very vivid comparison between the types of closures. A comparative analysis between different types of closures in various application areas outlines each of its benefits and drawbacks with respect to its suitability in fishing boot (see Table 4). Thereby, a rational deduction is made towards an innovative solution in the form of a fastening concept and utilized in a suitable application.

**Summary**

This chapter outlined the background of the study herein and highlighted some of the existing problems emphasizing the increasing demand for improved fastening systems in fishing footwear (including shoes and boots). A better understanding of the design problem was obtained through these analysis and reviews – towards achieving our first two objectives presented in chapter III which were:

- Understand the functioning requirements of the product-fishing footwear
- Identify design issues through user reviews and interaction with market professionals from retail perspective.

The establishment of design criteria in various fishing-sports footwear indicated the functioning requirements of the product. Furthermore, the reports and comparative analysis of different closures in top-rated models clearly identified the potential design improvement areas in closure systems. Assessments of anglers' environment, tasks and activities requirements, and analysis of precedent designs available on the market are essential in developing the optimal

design solution. The detection of plausible shortcomings/ hindrance in utility of fastening applications related to fishing sports helped make an informed decision in upcoming ideation process. In this way, the user needs could be integrated into creating a design solution as an improved fastening system.

CHAPTER V

# Concept Development and Design Selection

This chapter reflects the iterative design process through translating the identified design parameters (uncovered in the previous chapter) into developed design models, after series of alteration and selection. Analysis of market reviews and assessment of different types of closure application in sports footwear in chapter IV was utilized in conceptualization of designs. The conceptualization includes the ideation boards and development of concept proposals. The test concepts are then sent out to Footwear Design experts from the industry with a survey questionnaire for selecting a single design solution, based on the survey results.

## Concept Development Phase (Stage III)

A good concept development is crucial since is the foundation for the product development effort. Through an incremental and iterative process, identified ideas are taken from birth to mature tangible concepts. This stage presents the initial concept proposals that have been created from the research. Each attempt is made to display attributes that can offer a fastening solution for the fishing footwear optimizing protection, fit and mobility for the anglers. The concepts have been generated from ideas intuitively developed from the research. The proposals are presented with a conceptual sketch and an elaboration on the conceptual idea. The proposals are further segregated into two stages of presentation, reflecting the ideation process and refined technical model.

### *The Ideation Process*

Ideation is all about coming up with the big idea. However, the key challenge is to understand what constitutes a big idea. The goal is to construct the single, best solution to satisfy

the unmet fastening needs in footwear, enabling the anglers to secure their feet, get the job done faster, more conveniently, and more effectively than ever before. The hoard of ideas obtained from this ideation stage is filtered, assessed, generated, and developed in terms of finalizing the shape/form/closure mechanism in the footwear. In the process, ideas which are intuitively appealing and address unmet needs of functional gear (i.e., fishing footwear) take precedence.

It was discovered (from previous chapters) that fishing footwear has few functional requirements of good fit, protection and mobility. These parameters were considered when assessing how well a fastener enables the fishermen to successfully execute fishing activity. Prior to ideation, various shoe closures and top-rated fishing footwear product reviews was explored and analyzed to capture and prioritize all the anglers' needs. Study of literature and market reviews also pointed out some existing problems in traditional closures to address, with a sound understanding of strengths and weaknesses of different types of closures from other lifestyle products. Ultimately, this helped finding the big idea through an iterative process.

Concept design generally means the use of hand-drawn or digital sketches to convey what's in a designer's mind onto paper or a screen. It can, however, also include sketch models or shape and form studies in a variety of mediums such as paper, plastic-card, cardboard, clay or foam. Digital sketch models have been used to explore early ideas, along with digital and hand-built mechanisms. The idea was to get several good ideas down quickly and relay multiple thoughts and ideas at a glance. The main focus at this point is to convey imagination and fresh thinking and not focus on or 'noodle' one idea. Multiple sketches are created reflecting differing ideas or sketches that, through iteration, improve the theme and direction of the brief. Reference to an existing invention or brainstorming lines from inspiration objects might be included in

ideation process. The ideation stage tends not to be very focused at this stage, as things like steps of closure mechanism may not even have been selected this early on. Regardless, this early review will still serve as a test to see if things are going in the right direction. Finally, a few focused reference sketches or photo images can be added to convey a possible direction.

***Technical Approach***

Repetition and alteration of one design was reserved for the later stages of the process Repetition and alteration of one design was reserved for the later stages of the process. Any mechanical and technical limitations are taken into account while brainstorming, but the concept is not limited by these boundaries.

A functional gear (fishing footwear) involves stringent needs to be fulfilled; hence, a perpetual battle of style versus practicality can be envisaged. Hence, it was better to tone down the extravagant or imaginative than it is to jazz up a functional yet boring solution. Of course, a practical and functional product sells, but consumers are also driven by desire.

For the design selection study, it is pertinent to present the concepts in a presentable and interpretable form that constitutes the basis for review and evaluation by design experts. In this study, these forms involved imagery and more detailed information that contain all the relevant call-outs and illustrations to successfully describe the fastening system at a one minute glance. Features such as a mechanical specification and step-by-step functioning and usage of closure were outlined. However, the potential utility, expectations, and underlying intelligence or practical functioning associated with the concept is not included. Any other specific inputs like colors and new materials were also not mentioned.

***Initial Concept – Proposals and Iterations***

The concepts were proposed and elaborated by theorizing strengths, weaknesses, concerning the creation of fastening systems to meet the needs of the fishing folks (improving fitting, protection and mobility). There were a total of five design concepts of fasteners, designed specifically for fishing footwear. Each of the concepts included illustrations of both ideation step and the technical bit separately. Performance specifications and mechanism was explained in detail in the narration, following the illustrative images.

**Design 1: Buckle with Dial System:** The ideation process started with inspiration from helmet dials and measuring tape ratchets closure, which could be pulled or pushed and locked with a slide of a lever. A similar fastening concept is used in helmets; the straps are tightened and loosened with a push dial (see Figure 21). The Spin Dial in helmets has pleased users, because it helps to achieve the perfect snug fit, the spin dial works a bit more effectively and sensitively (Nutcase, 2015).

The closure mechanism, for the first concept, has a push dial on the side of the shoe, which is equipped with a very neat handle that adjusts the length of the steel cable wire, one threaded through the strap's mounting points (see Figure 22). Just turn the dial and the wires tighten to form a comfortably stable envelope around your foot. The boot will obtain its perfect fit, and never loosen or come untied.

To remove, the user may simply pinch both side small surfaces around the dial and the cables instantly releases. For significantly bigger length adjustments, there is an innovative red button which can be pushed to lift the buckle and adjustments are made easy. The red button basically releases the ratchet lever making adjustment. Lifting up the buckle adjusts the fit along the entire length of the shoe, adapting the upper to the shape of the foot for a customized fit.

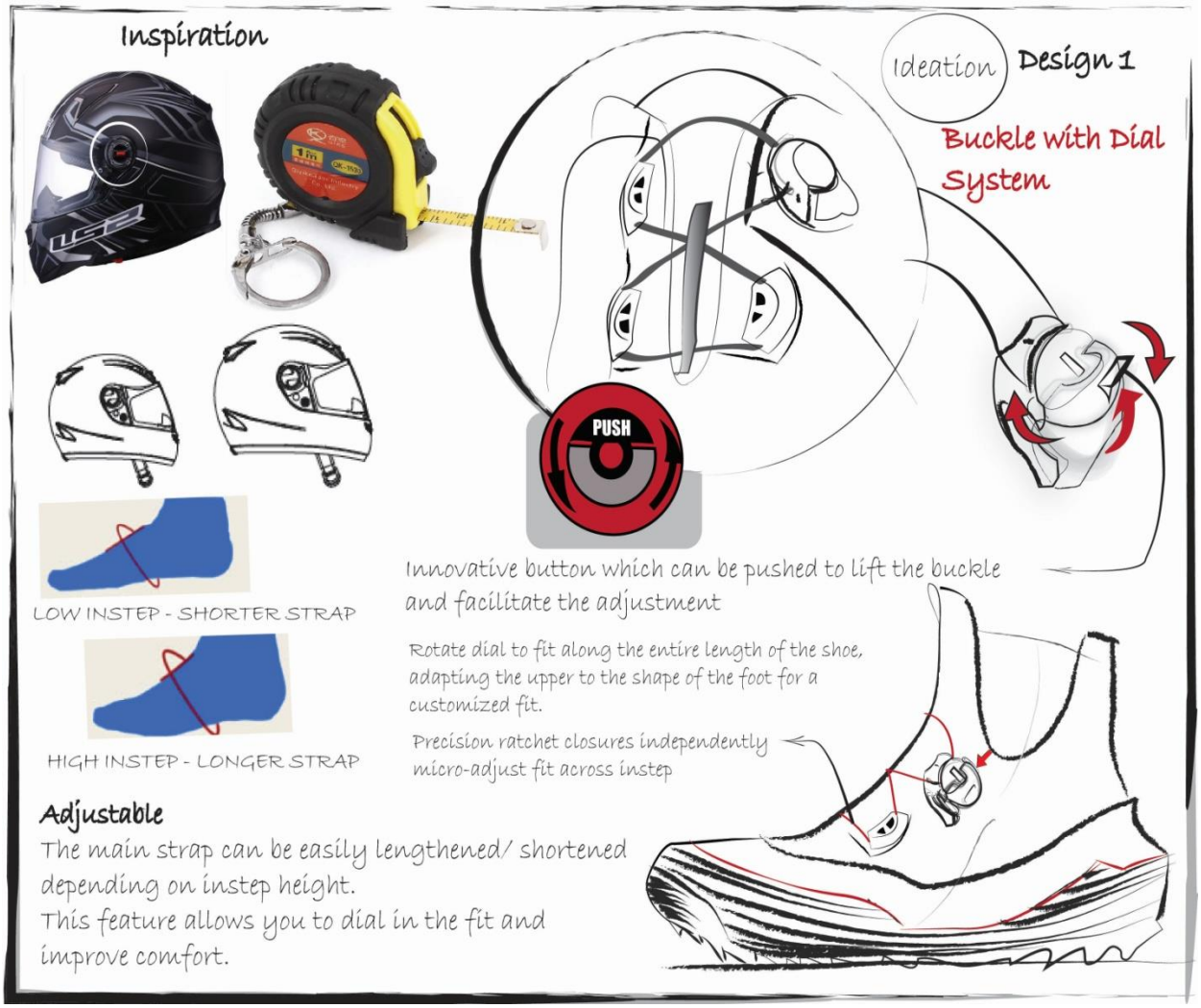



Figure 21: Design 1 - Ideation

For instance, a fit could be achieved so perfectly with exact length adjustment of the wire that one does not have to resort to really tightening the dials. Furthermore, a simple, quick release buckle retention system that, once adjusted, can be buckled and unbuckled without changing the adjustment.

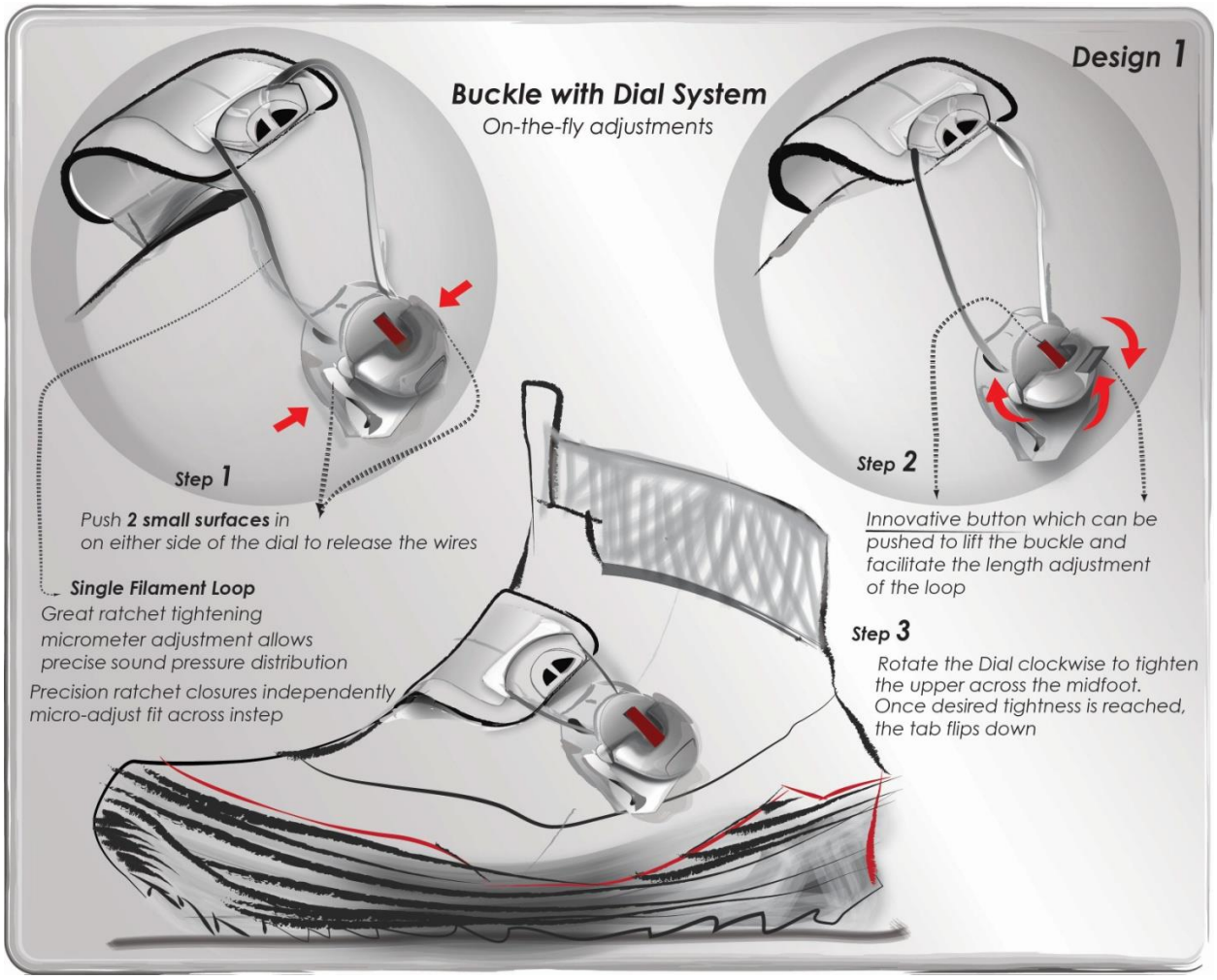



Figure 22: Design 1 - Technical

Dial rotation is an added feature for facilitating very small increments, during the activity. Its ratcheted adjustments are placed at short increments, offering an impressive degree of adjustment and allowing precise sound pressure distribution across the instep area. The mechanism is described as “micro metric” – an accurate enough description. Not only does the dial offers a greater degree of micro adjustability, but it also provides fit consistency across the entire shoe. This ensures that one gets the perfect fit every single time he/she buckle up for an activity.

A wide curved thermo-foamed EVA padded strap not only holds the threaded mount for passage of wires, but also evenly spreads pressure across the top of the foot. The symmetrical mechanism guarantees an excellent closure adapting on every instep. The convenience advantages are also significant. It is vastly easier and faster to put your shoes on and take them off. Anglers can wear their shoes loose and comfortable for an instant break and then quickly tighten them up for super support during fishing. There will be no more hassle of a loose shoelace ends in the way when the shoes are on or off, as the wires wind up inside the reel. Tightness can be fine-tuned by dialing in perfect closure force.

**Design 2: Four-point lock Magnetic Harness:** The ideation process involved rigorous brainstorming sessions and doodling with different forms molding into structure of the foot (see Figure 23). The idea was to create a suitable shape of the closure according to the anatomy of the foot, such that it gives a secure, superior coverage all over. The derived shape was initially inspired from a child's car seat, which is a proven product of secure locking and ultimate protection.

A method was found to intelligently combine the advantages of two tried-and-tested fastening concepts – those of a magnetic and a mechanical fastener. It was not simply a case of adding functionality; the individual advantages were successfully combined the individual. The combination of a magnetic fastener with mechanical snap functionality: strong magnets make the fasteners easy to close and secure snap functionality ensures a continuously high locking force. The functionality of a traditional, mechanical fastener, for example, is always the same, just like a door: press the handle – open, close. But in this design model, magnets close it automatically, and the fastener snaps securely closed. The fastener is opened through lateral

sliding (see Figure 24). It enables virtually automatic closing and allows the fasteners to be opened in a user-friendly manner with just one hand – even when wearing gloves. When the fastener is closed, the magnets are held together securely by attractive force, allowing for a particularly high closure force.

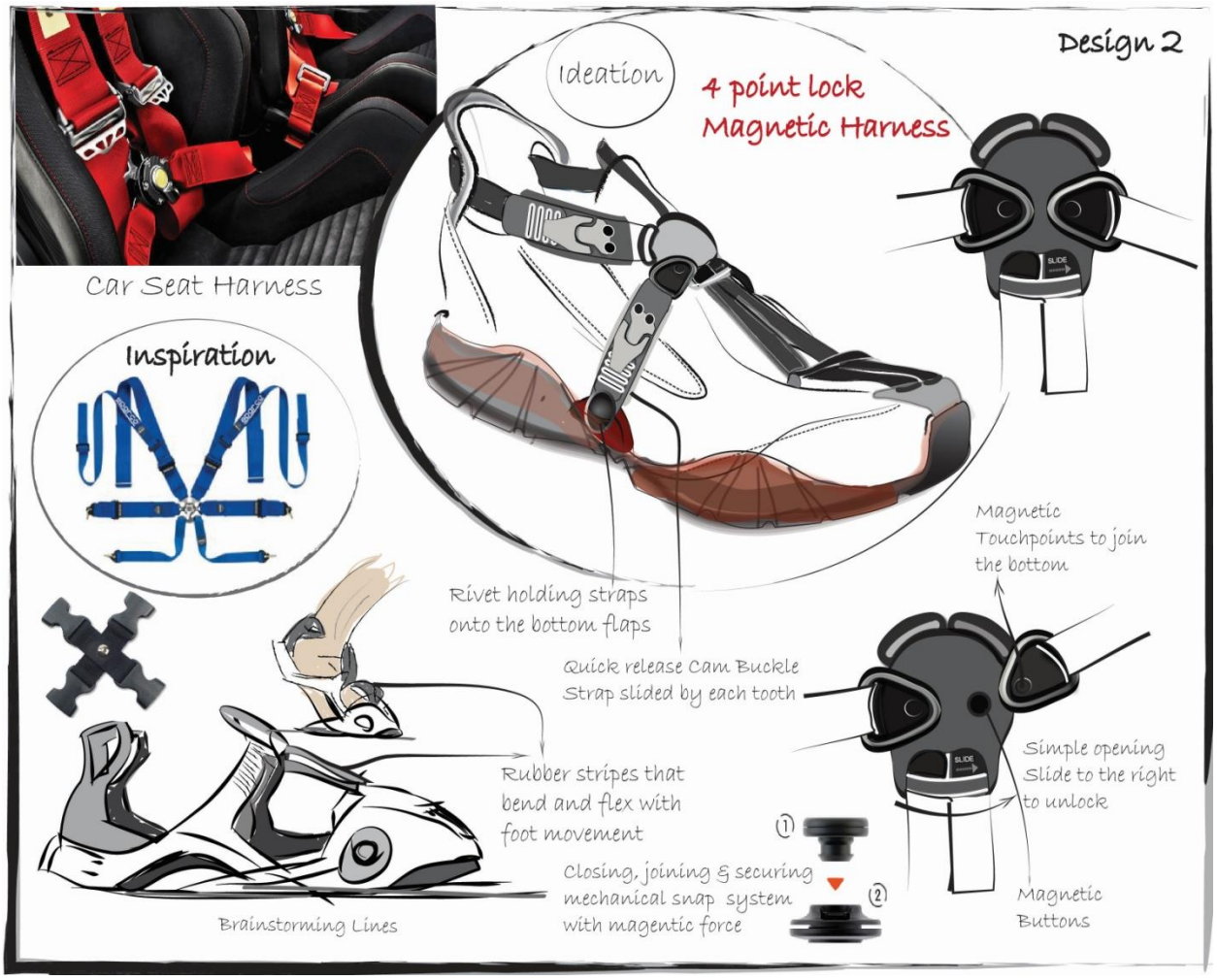



Figure 23: Design 2 - Ideation

The magnetic closure is complimented by mechanical locking, which securely and reliably fixes the fastener in its closed state. The fasteners are also highly reliable, robust and secure. This is made possible by the use of slidable magnets combined with stable mechanical locking. It is a perfect closure for applications with four-point straps.


Figure 24: Design 2 - Technical

**Design 3: Tightening Dial System:** As mentioned and reviewed in the section of "analysis of different closure" before, there are existing cutch reel technology (similar dial tightening mechanism) in medical products (see Figure 21). People complain that the single dial boots have pressure points and it only control the pressure in positioned area. Table 4 shows that the dials have a major disadvantage in controlling pressure points only in its positioned area. This may cause fit and mobility issues, as the pressure distribution across the feet remain uneven.

Thus, the ideation process involved lot of brainstorming in positioning of dials to optimize flexibility in fit adjustments.

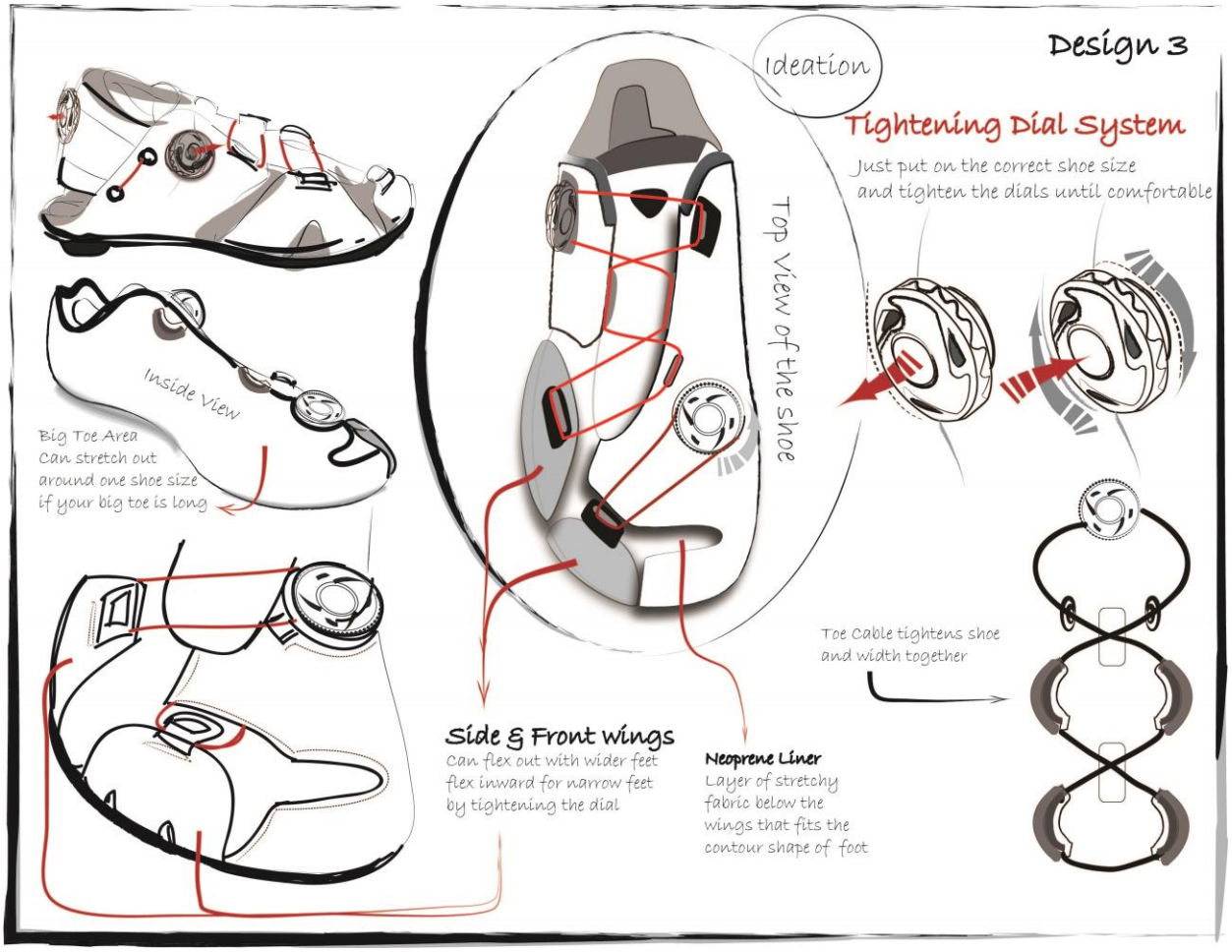



Figure 25: Design 3 - Ideation

The shortlisted ideation, utilizing tightening dial system, is designed to be a generic solution, irrespective of the individual's foot shape. The design of the shoe and its innovative accommodation of two tightening dials allow easy adjustment of both length and width. Simply loosen the dials and unhook the cables to reroute them and find the perfect fit for the foot. What makes this closure different is that the toe box's length & width are adjusted independently from

the rest of the shoe and one can “lace” the shoes in several ways to best fit the width and shape of the foot.

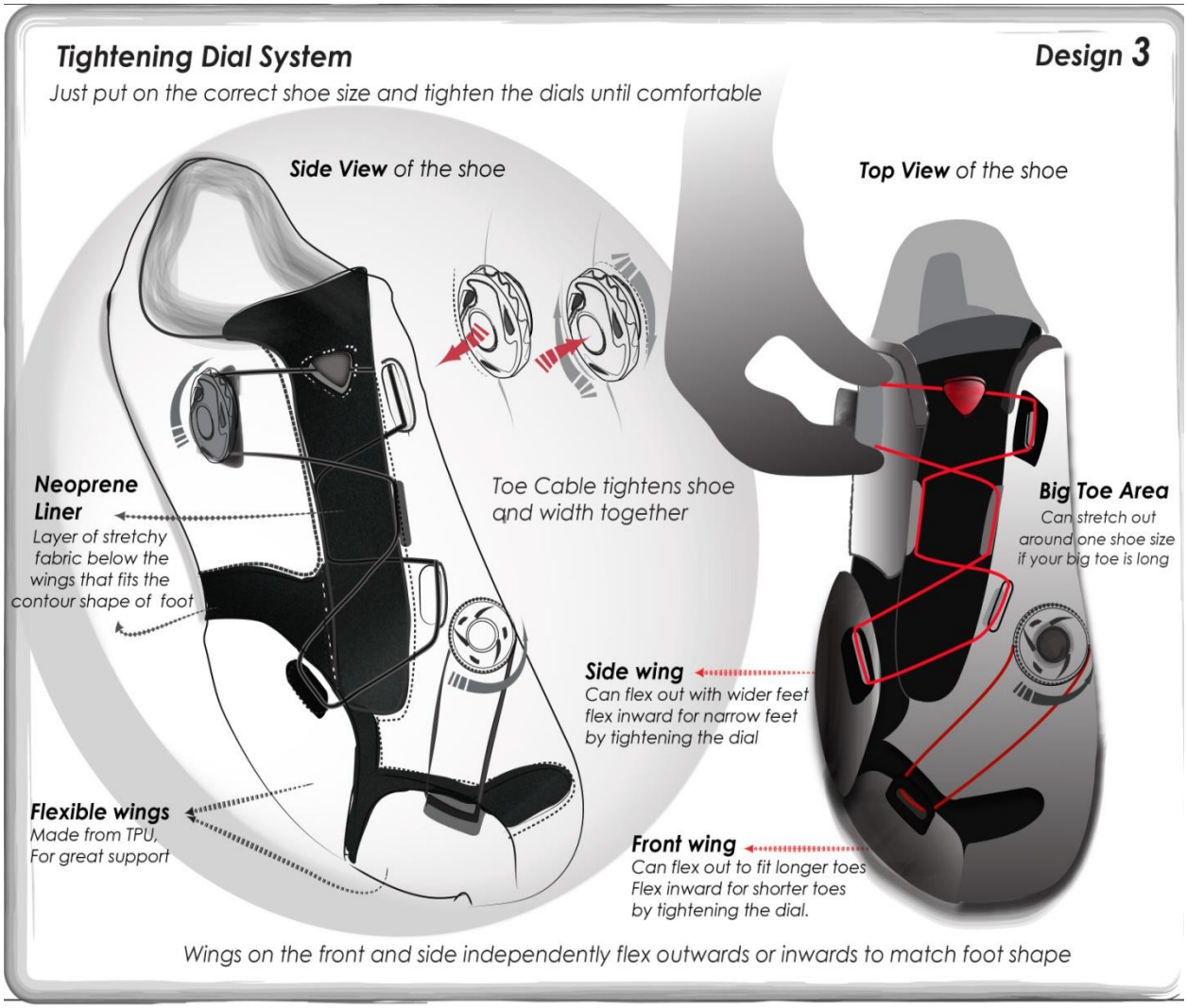



Figure 26: Design 3 - Technical

The basic illustrations in Figure 26 show how the shoe can be configured using a combination of the dial and elastic cable. The side and outer front corner of the shoe have independent “wings” made of TPU, (thermoplastic polyurethane) that can be adjusted to the foot’s width and let the anglers fine tune the length with the pull of cable wire.

The independent wings are attached from the bottom side of a stretchable neoprene liner that offers flexibility and moving space with apt adjustments. An elastic cable comes with the shoe so that it can provide elasticity rather than a “fixed” width to the shoe whereas the parts controlled by the dials would have more of a “fixed” position.

The performance advantages are significant because there are no pressure points. Due to the unique lace guides and precise closure, pressure points are eliminated. The lace guides provide perfectly distributed closure force across the eye-stays. The fishermen can adjust tightness minutely and instantly to dial in the perfect fit every time. On-the-fly adjustments like this are impossible with shoelaces. The closure is solid because it cannot get loose. As the shoe itself stretches through the course of the day, a quick turn of the dial tightens it back up again. The lacing system provides a dramatic improvement over shoelaces for almost any kind of fishing shoe that require controlled closure.

**Design 4: Calibrating Buckle with Micrometer Gauge:** The idea started with an attempt to create an ultra-minimalist, yet an innovative fastening system. The shape has a clean look and is well balanced with full frontal adjustment, provided by calibrating buckle and a secure back counter closure with high-security Velcro. Simple functionality and user interaction describes the uniqueness of this model. The intention was to give the user maximum freedom of flexing with cross over straps all over the foot, with which one could accommodate all the extensions during the activity (see Figure 27). The micrometric closure called “calibrating buckle” ratchets in both directions, allowing for precise, incremental tightening and loosening of the closure, for easy on-the-fly micro adjustment. It is adjustable by lifting the central buckle. Pulling upward on the lower ratchet lever tightens the strap, click by click; push the center button

to slightly loosen one tooth at the time; an outward pull on both side levers completely releases the buckle (see Figure 29).

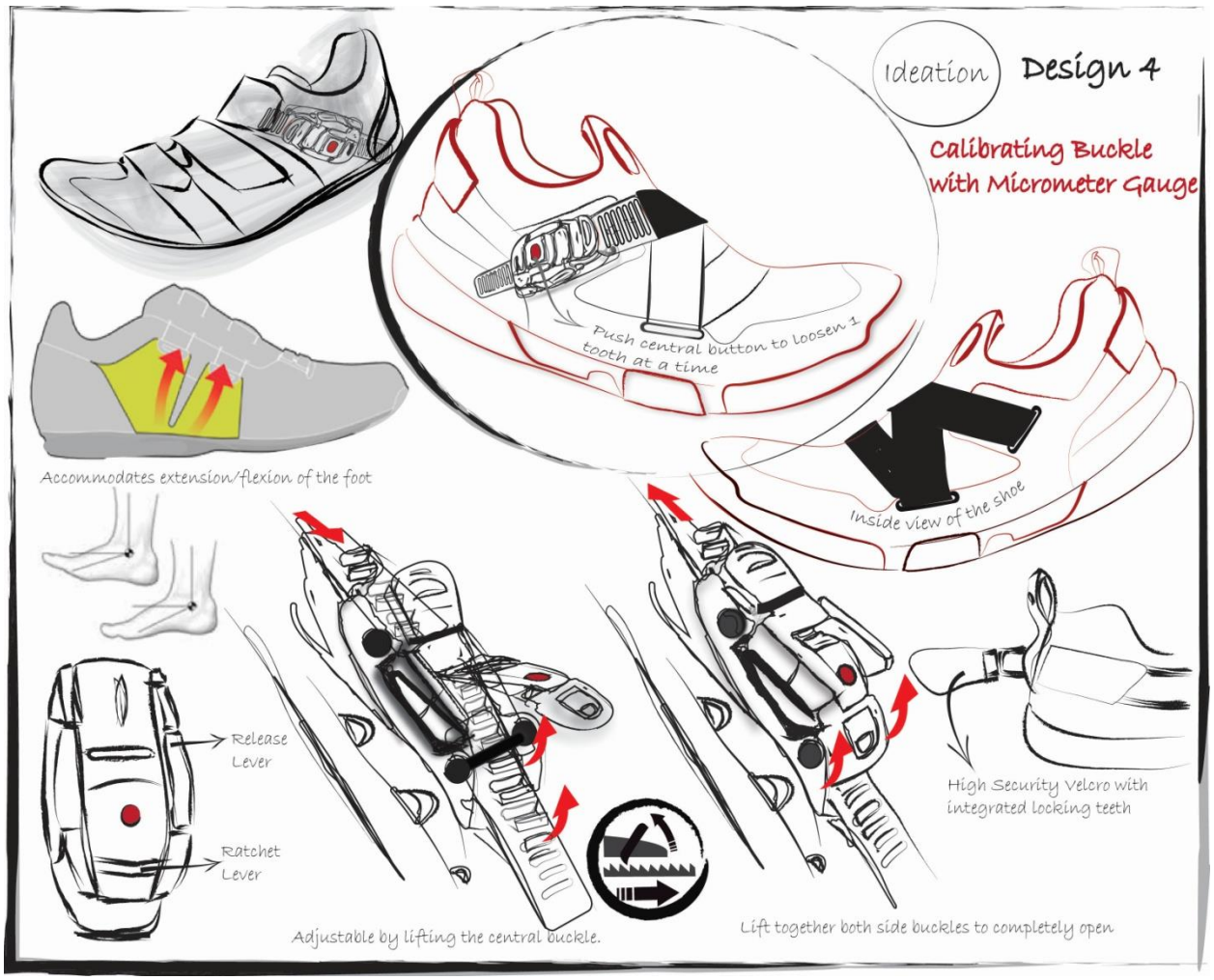



Figure 27: Design 4 - Ideation

This compact intuitive closure system allows for quickly opening and snugging up the shoe as well as making small fit adjustments on the run. As the anglers stay in water for long periods of time, their feet may swell a bit. Anglers can loosen the buckle by pushing down on the central clip. To completely open the straps, lift both side buckles at the same time. The ratcheting buckle closure combines the robust holding power and on-the-fly adjustability of upper straps with the strength to withstand the powerful, repetitive walk/movement during the activity.

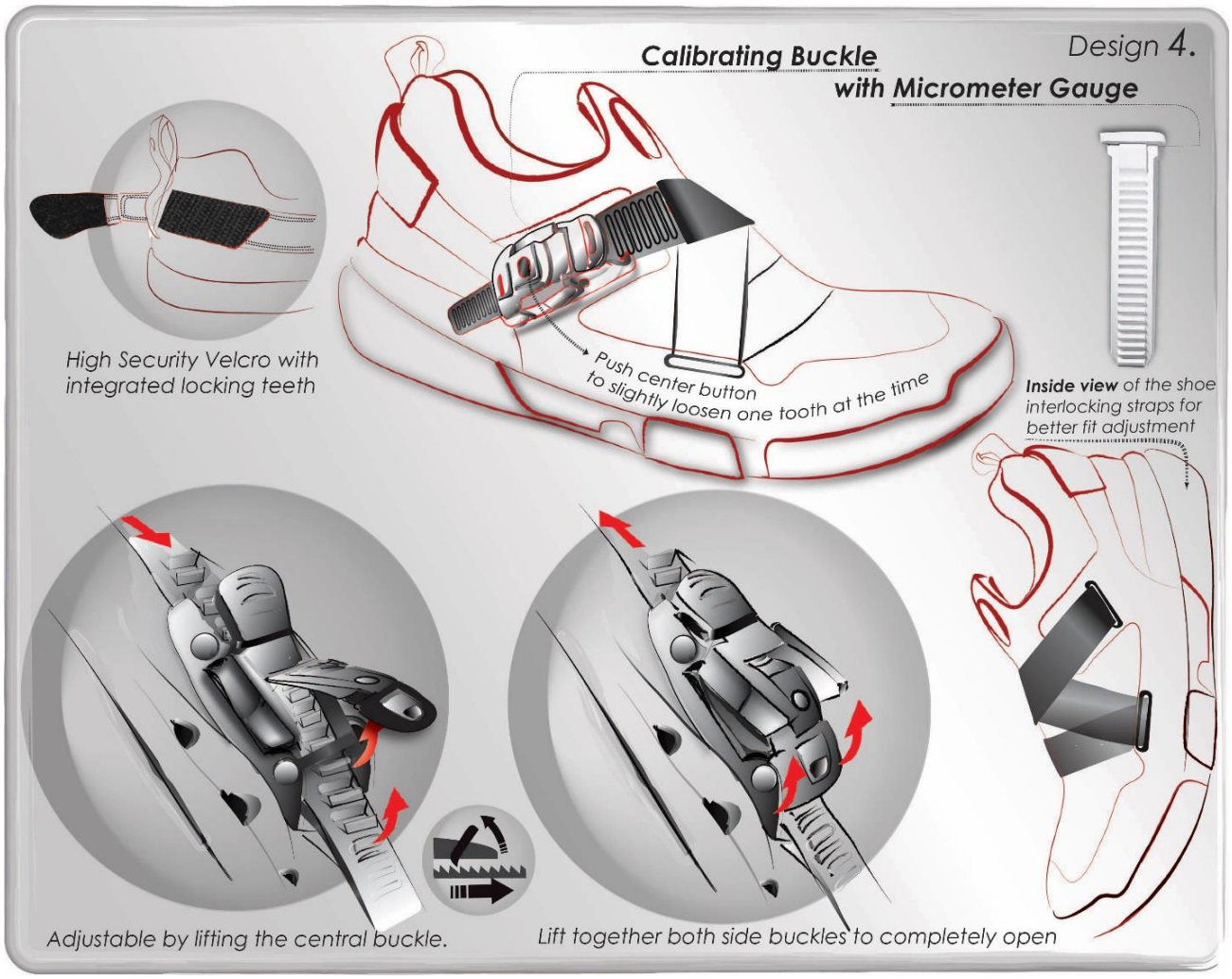



Figure 28: Design 4 - Technical

These buckles have great durability and superb function through a clever ratcheting system that offers a tactile feel when adjusting buckle tension. The buckle is truly micro-adjustable in tension and release, allowing two-way adjustment gauge in 2mm increments by simply pulling up to tighten the strap or depressing the lever to release it. This concept also features a quick macro-release for easy removal of the shoe. The design allows grit to be cleared easily for reliable function on- and off-trail.

Figure 29: High-security Velcro

Crisscross straps ensure that the gauge stay stylishly in place. Straps go around the foot and shoe and hold the foot in place really well. High security Velcro is a double secure closure at the back of the shoe for further holding back of heel during rigorous movement activity. It has interlocking polymer teeth that engage when the strap is closed to provide a more secure, slip-free closure that is designed to increase the useful life of the Velcro strap (see Figure 29). This feature makes the closure more secure and the strap becomes unmovable.

**Design 5: Double Closure System**: The ideation of this model transcends traditional fishing footwear, drawing conceptual inspiration from mountaineering boots. Despite looking at the construction from a mountaineering boot point of view, they hike and protect more like a fishing shoe. The design of the boot is primarily inspired from integrated gravel guards, which are considered as an important gear in fishing activities (see Figure 30). The boot is actually made of an inside boot within an outside boot, although they cannot be taken apart. This allows the inside boot closure to focus on comfort and fit and the outside boot to focus on protection and water resistance. There is an inner boot and an outer shell. The inner boot is the insulation and the outer one is the environmental protection. Although this fishing boot is single layered, it has two part construction, with an inner boot with traditional cord lace closure, and the outer boot functions as a mid-calf gaiter with a zippered closure and a hook-and-loop flap.

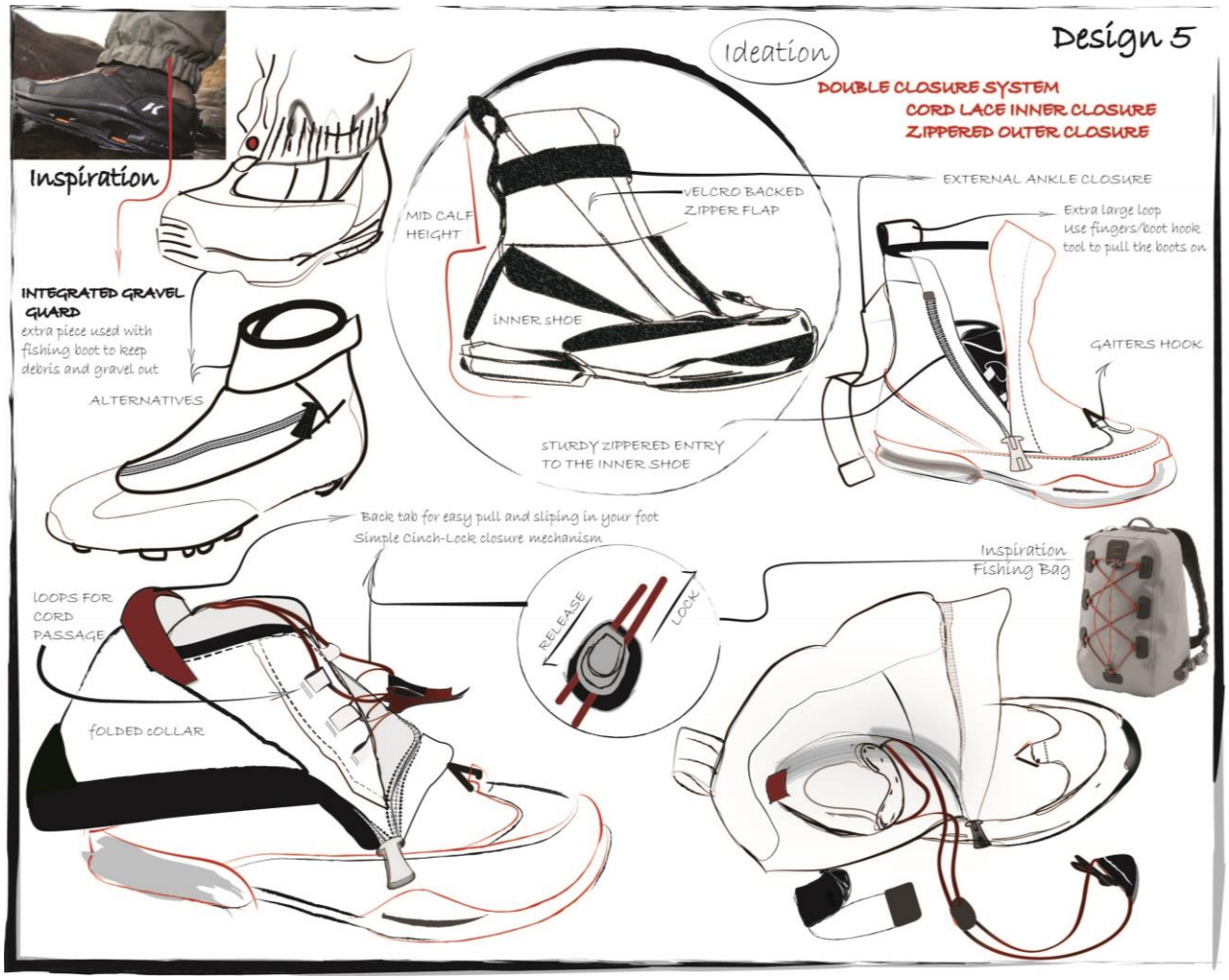



Figure 30: Design 5 - Ideation

The outside of the boot features a waterproof-breathable membrane, which allows moisture from the inside, such as perspiration, to get out, while blocking water from the outside from coming in. The inside part has a pull-up so that anglers can hold onto it when inserting their foot. It is designed well to secure from any unpleasant wear spots, as it provides a very smooth, covered closure. The boots are kept snug by a draw cord, and the outer shell closes with a zipper and Velcro flap to keep out the dirt, debris, gravel and mud from the river. The breakage of zipper closure should be the least of concerns as it is well protected by the extra large flap and

additionally secured by Velcro backed strap. The strap at the top of the boot also allows a snug tight for wearer.

The inner shoe has a gusseted tongue with a drawstring closure, which could be cinched down the cord straps as tight as they would go. It works well without adding unnecessary complexity. Once the foot is placed inside the inner boot securely, a water-resistant outer zip up with a water-resistant zipper that is locked down with a Velcro strip.

The front of the boot features a hook to allow for the use of gaiters (see Figure 30). For deep water fishing, a knee-high gaiter could be easily added using the dedicated hook on the toe box. This is often added by the anglers for extra protection from gravel and is commonly known as “gravel guard”. As seen in the ideation graphics, the concept is derived from integrated gravel guards, which is used as an important gear in fishing activities.

Overall, the closure system has less moving parts which means fewer things that can fail. It could be a good choice for transition seasons as this model is designed specifically for keeping the light snow and water out. With the new pull-lace closure, there is really no passage for dirt/debris to block up the system. While there is a Velcro strap across the top, since the strap is so high up the boot it essentially never encounters light snow, dirt or any other invasive species, meaning that even if one needs to adjust it mid-activity, it is likely to work fine.

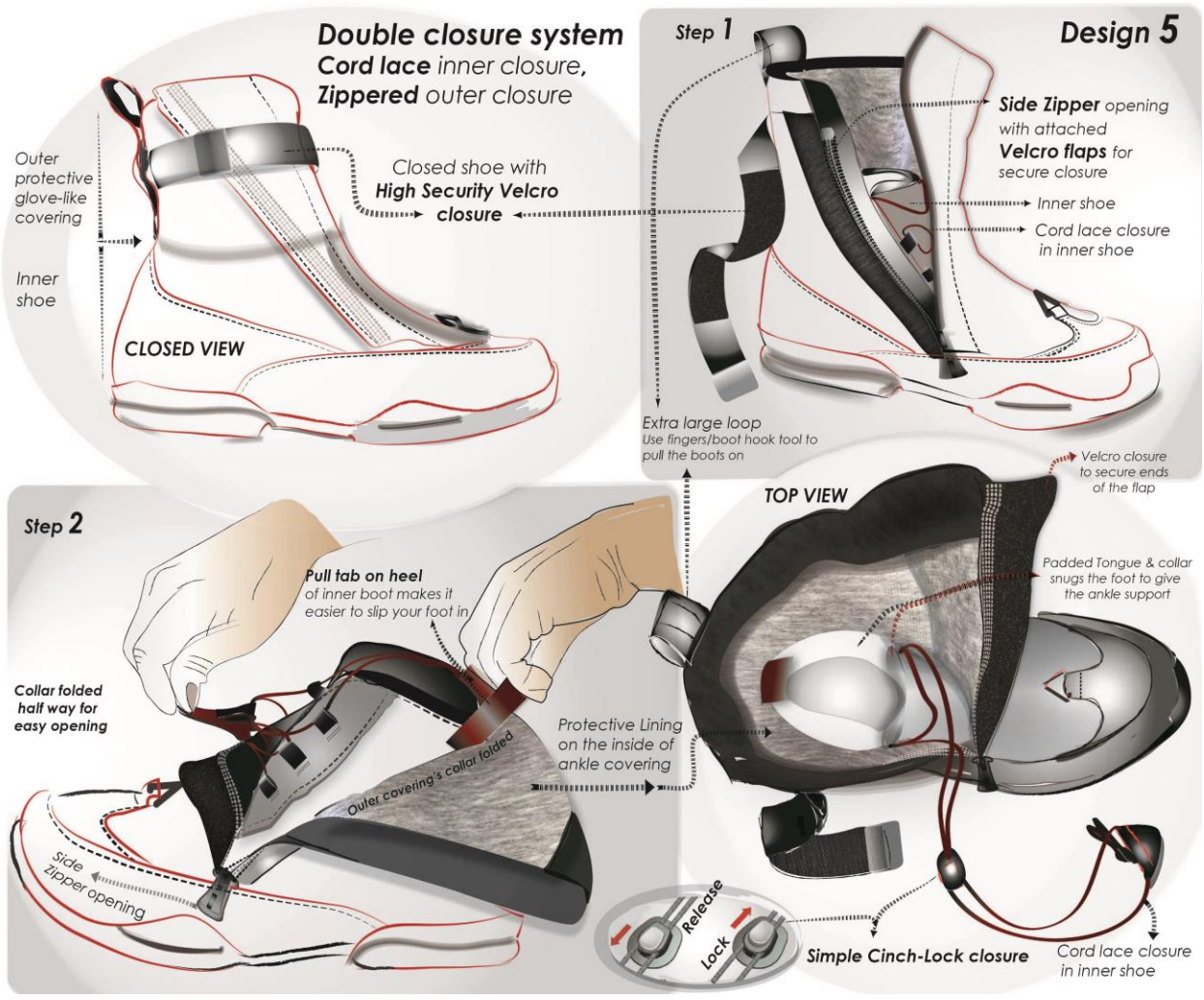



Figure 31: Design 5 - Technical

## Concept Selection

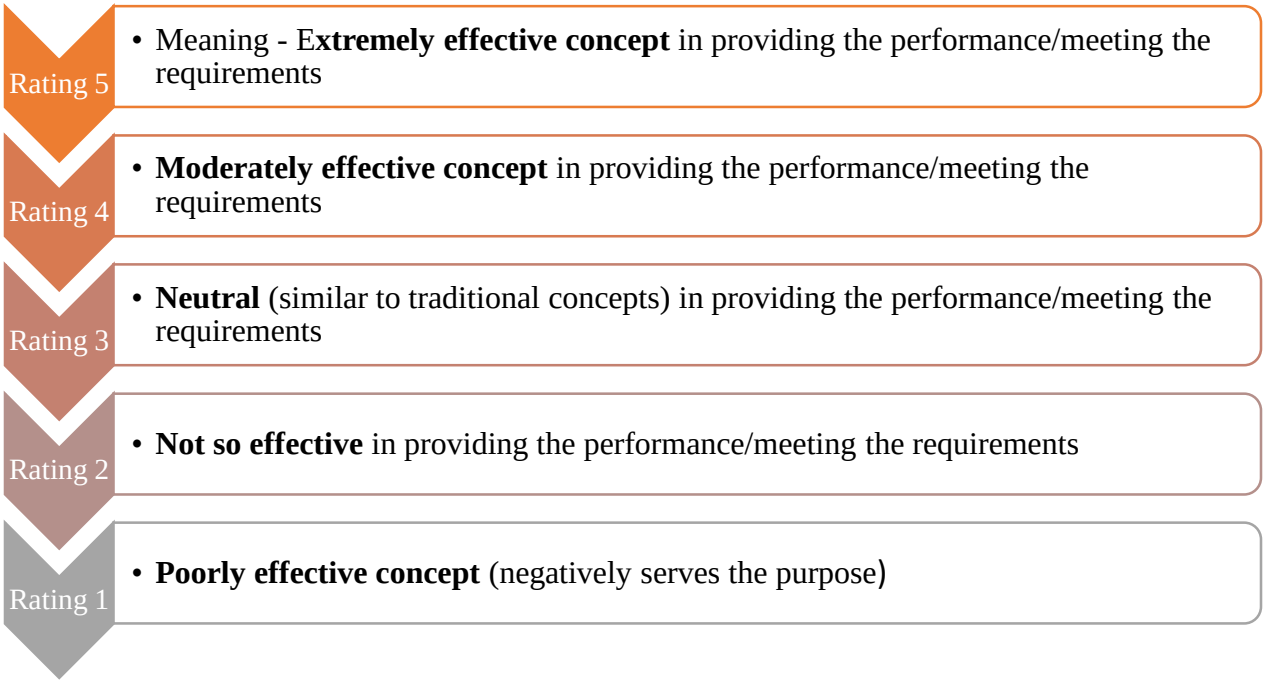
This project-based research aims to achieve feedback and validation from industry experts, who are pioneers of footwear technical design field. The purpose of the concept evaluation stage is to hand-select a fastening concept for fishing footwear among various conceptual illustrative designs, from a utility and retail viewpoint, using feedback from various footwear design experts. Therefore, design professionals were approached directly. Design professionals working in sports industry were also approached through relevant education seminars and conferences. Upon receiving their consent and mutual interest in this research, expert reviewers were identified and recruited. The identity of the reviewers is well-protected and is held as confidential as possible.

### *Ethical Issues*

The concept selection of design proposals involves human participants (e.g., Footwear Design Professionals from the outdoor sports industry). According to West Virginia University's institutional Review Board, ethics approval is required for any human participation and involvement in research activities. For this study, approval was granted for exemption. To keep participants' personal information confidential, all raw data and documentation is kept anonymous and accessible only within the personnel involved in this study. Presentations and publications in any forms resulting from the study do not disclose participants' identification. Upon ethics approval, the procedure of recruiting participants and conducting research proceeded.

### *Instrumentation*

The evaluation technique used required a comparison between the concepts developed and the requirements they must meet along with decisions regarding how well they meet those requirements. In order to evaluate concepts effectively, some form of criteria was needed against which concepts can be evaluated in a quantitative fashion. The criteria for the concept-selection matrix were based on the functional requirements and/or the objectives of the problem. Therefore, a questionnaire was designed and distributed by e-mail with four constructs for measuring performance features: protection, fitting, mobility and general requirements. Individual items in the categories of each construct were structured for the information on specific functional requirements of the outdoor gear; fishing footwear. The criteria for deciding which concept is better than the other are determined by the specific features and fastening mechanism of each closure that is implemented to suit the demands of fishing activity. The opinion rating is taken using a linear 5-point scale matrix, on each of the concept of fastening systems in fishing footwear. The weighted score is simply the rating for a given concept and criterion. The weighted scores are then summed, and the concept with the highest score is selected.




Additionally, in a separate section of the questionnaire, an open feedback area was provided for the experts to comment on their overall perspective related to the designs. The instrumentation is given in Appendix B.

***Data Collection Procedures***

Data collection procedures followed recommendations of Dillman et al. (2009). The survey questionnaire with technical design packet was sent electronically to the expert reviewers-A1 and A2. Apart from the questionnaire and technical design folder, the email attachment of the packet includes – Cover letter (see Appendix A) stating the purpose of the study, a request of co-operation, protection provided to the respondent, study requirements, promise of results, appreciation and request for immediate return.

***Population***

The target population for this questionnaire consisted of two industrial footwear design experts pursuing fishing activities as their hobbies. This creates a unique blend of qualities that were appropriate towards concept selection step for current study.

To ascertain confidentiality of the expert reviewers and to protect their identity in the research thesis, alphanumeric code numbers were assigned to each reviewer's name in the questionnaire. These codes have been used to identify their feedback in the thesis report. Expert reviewer I corresponds to A1 and another expert reviewer (II) from a different organization correspond to A2.

***Data Analysis***

Since the target population consists of two human subjects, an assessment of individual responses is possible and has been provided herein. Both reviewers provided additional feedback in the comments area, which have been discussed as individual scores were analyzed. The additional comments also serve as a way to ascertain consistency between the scores and their remarks. The scores have been listed in Table 5 and Table 6 for Reviewer A1 and A2 respectively. Upon comparison, it could be seen that both reviewers provide highest points to Design-1 based on protection, with Reviewer A2 assigning near full points to Design-1 on all questions pertaining to protection. It must be noted that Reviewer A1 has significantly discredited Design-3 related to footwear protection parameters.

On the mobility criteria, Reviewer A1 provides more points towards Design-1 and Design-4, closely followed by Design-3; whereas Reviewer A2 has chosen Design-1 and Design-3. In terms of fitting, Reviewer A1 finds Design-3 and Design-5 to be most beneficial. Reviewer A2 provides full points to Design-3 and Design-4 in all fitting related questions. Reviewer A2

further writes in the "additional comments" section that, "*Concept four has excellent use of a system with an adjustable tension and release on a shoe or boot design*."

Reviewers A1 and A2 find Design-2 to be most innovative. As stated by Reviewer A2- *"Concept two was also interesting, I like the seat belt reference and the overall ability to be able to customize fit with this design*". Reviewer A1 also finds none of the designs (except 5) to be beneficial in terms of ease of maintenance. Reviewer A2 provides high points to all designs, except Design-5, pertaining to general criteria such as innovativeness, diversity of application areas, commercialization standpoint and ease of maintenance. The only criticism with Concept Design-5 is that even though it is workable, it utilizes a few too many closure systems and requires the wearer to execute too many steps.

Table 5: Data collected from Reviewer A1 Questionnaire Response

***Reviewer A1***

**Part I: Protection**

| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|---|
| Secure | 3 | 4 | 4 | 5 | 5 |
| Clean look | 5 | 4 | 4 | 4 | 4 |
| Powerful lock | 5 | 5 | 5 | 5 | 4 |
| Lightweight | 5 | 3 | 4 | 3 | 3 |
| Durable | 4 | 4 | 3 | 4 | 5 |
| Fight water retention | 5 | 3 | 3 | 4 | 5 |
| Sturdy mechanism | 5 | 5 | 4 | 4 | 4 |
| Reliable | 4 | 4 | 3 | 4 | 4 |
| Fail-safe mechanism | 3 | 3 | 3 | 3 | 3 |
| No transport of aquatic invasives | 5 | 4 | 3 | 4 | 5 |
| Water protection | 4 | 4 | 3 | 4 | 5 |
| | 48 | 43 | 39 | 44 | 47 |

**Part II: Mobility**

| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|---|
| Fast on/off transition | 5 | 4 | 4 | 4 | 3 |
| Convenient | 3 | 3 | 3 | 3 | 3 |
| Freedom of movement | 5 | 4 | 4 | 4 | 5 |
| Less user-engagement | 3 | 3 | 4 | 4 | 3 |
| Easy maneuver | 4 | 3 | 3 | 4 | 2 |
| Cushioning and motion control | 4 | 3 | 4 | 4 | 3 |
| Easy opening | 3 | 3 | 3 | 3 | 3 |
| | 27 | 23 | 25 | 26 | 22 |

**Part III: Fitting**

| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|---|
| Micro-adjustability | 4 | 4 | 5 | 4 | 5 |
| Snug fit | 4 | 5 | 5 | 5 | 4 |
| Custom fit comfort | 3 | 4 | 5 | 5 | 5 |
| No pressure points | 3 | 3 | 3 | 3 | 5 |
| | 14 | 16 | 18 | 17 | 19 |

**Part IV: General**

| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|---|
| Most innovative | 4 | 5 | 3 | 3 | 2 |
| Diverse area of applications | 3 | 4 | 4 | 4 | 3 |
| Commercial stand-point | 5 | 5 | 5 | 5 | 3 |
| Easy maintenance | 2 | 2 | 2 | 2 | 4 |
| | 14 | 16 | 14 | 14 | 12 |

**Part V: Total**

| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|---|
| Protection | 48 | 43 | 39 | 44 | 47 |
| Mobility | 27 | 23 | 25 | 26 | 22 |
| Fitting | 14 | 16 | 18 | 17 | 19 |
| General | 14 | 16 | 14 | 14 | 12 |
| Weighted Avg. | **27.4** | **25.7** | **25.4** | **26.9** | **26.9** |

Table 6: Data collected from Reviewer A2 Questionnaire Response

***Reviewer A2***

**Part I: Protection**

| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|---|
| Secure | 5 | 5 | 5 | 5 | 4 |
| Clean look | 5 | 4 | 5 | 4 | 2 |
| Powerful lock | 5 | 4 | 5 | 4 | 5 |
| Lightweight | 5 | 4 | 5 | 4 | 4 |
| Durable | 5 | 4 | 5 | 4 | 5 |
| Fight water retention | 5 | 4 | 4 | 4 | 5 |
| Sturdy mechanism | 5 | 5 | 5 | 5 | 5 |
| Reliable | 5 | 4 | 5 | 5 | 4 |
| Fail-safe mechanism | 4 | 4 | 4 | 4 | 3 |
| No transport of aquatic invasives | 5 | 4 | 5 | 4 | 4 |
| Water protection | 5 | 4 | 4 | 4 | 4 |
| | 54 | 46 | 52 | 47 | 45 |

**Part II: Mobility**

| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|---|
| Fast on/off transition | 5 | 4 | 5 | 5 | 3 |
| Convenient | 5 | 4 | 5 | 5 | 3 |
| Freedom of movement | 5 | 5 | 5 | 5 | 3 |
| Less user-engagement | 5 | 4 | 5 | 5 | 3 |
| Easy maneuver | 5 | 4 | 5 | 4 | 3 |
| Cushioning and motion control | 5 | 5 | 5 | 5 | 4 |
| Easy opening | 5 | 4 | 5 | 4 | 3 |
| | 35 | 30 | 35 | 33 | 22 |

**Part III: Fitting**

| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|---|
| Micro-adjustability | 5 | 5 | 5 | 5 | 3 |
| Snug fit | 5 | 5 | 5 | 5 | 4 |
| Custom fit comfort | 5 | 5 | 5 | 5 | 3 |
| No pressure points | 4 | 4 | 5 | 5 | 3 |
| | 19 | 19 | 20 | 20 | 13 |

**Part IV: General**

| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|---|
| Most innovative | 5 | 5 | 5 | 4 | 3 |
| Diverse area of applications | 5 | 5 | 5 | 4 | 3 |
| Commercial stand-point | 5 | 5 | 5 | 5 | 3 |
| Easy maintenance | 4 | 4 | 4 | 4 | 4 |
| | 19 | 19 | 19 | 17 | 13 |

**Part V: Total**

| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|---|
| Protection | 54 | 46 | 52 | 47 | 45 |
| Mobility | 35 | 30 | 35 | 33 | 22 |
| Fitting | 19 | 19 | 20 | 20 | 13 |
| General | 19 | 19 | 19 | 17 | 13 |
| | **33.6** | **29.9** | **33.3** | **31.0** | **24.7** |

In addition to individual assessment provided above, an overall assessment is required based on certain statistical analysis, to obtain a conclusive design selection. Table 7 shows the responses as mean average scores of both the reviewers. Assessment of each criterion (fit, mobility, etc.), has been depicted visually as percentage values corresponding to each design for ease of interpretation and analysis.

Figure 32 shows the average design ratings related to footwear protection. Design-1 is a clear winner pertaining to "protection" parameter with highest accumulated points – 51 (out of a total of 55.0 points). According to the reviewer A2, Concept 1 is the most viable design idea because it offers the cleanest look and the easiest entry system.

This design also captures the maximum percentage points (22%) relative to other designs. On "mobility" criterion, Design-1 is again a preferred design with 31.0 points (total of 35 points), closely followed by Design-3 with 30.0 points. Both of the designs have the maximum percentage points (22%) among the five designs according to Figure 33. This may be due to its potential in wider applicability and suitability in the outdoor category of fishing, hunting and general outdoor use, as stated by the Reviewer A1.

Design-3 is selected as the best related to the "fitting" criterion, with near-perfect points of 19 (total of 20 points). Design-1 is the preferred design in protection and mobility areas while it is not preferred to suit the "fitting" criterion with a percentage point of 19%, as opposed to 22% for Design-3 (see Figure 34). Intuitively, this makes sense because of its flexibility in lacing technique, which could be laced up according to the need of custom fitting in particular areas of foot (instep, toe area, heel). Concept 3 is Reviewer A2's personal favorite because it has infinite possibilities in its uses and adaptability in fit, comfort and technical ability.

Figure 35 gives pie charts showing mean design ratings related to various miscellaneous parameters such as innovativeness, commercialization standpoint, etc. Based on average scores, Design-2 is rated the most innovative. Particularly mentioned by the Reviewer A2 - *"Concept two was most interesting, especially the seat belt reference and the overall ability to be able to customize fit with this design".* However, there was a criticism from Reviewer A1 stating that, *"Concept two has an external fixation system and anglers may run the potential for the fishing line and hooks getting caught on the loose straps".*

Both Design-2 and Design 3 are rated to be most diverse in application. All of the designs, except Design-5, are deemed to be of good commercial value. However, Design-5 is rated as the most beneficial in terms of ease of maintenance.

Table 7: Mean Average Scores of Questionnaire Responses

| Part I: Protection | | | | | |
|---|---|---|---|---|---|
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
| Secure | 4.0 | 4.5 | 4.5 | 5.0 | 4.5 |
| Clean look | 5.0 | 4.0 | 4.5 | 4.0 | 3.0 |
| Powerful lock | 5.0 | 4.5 | 5.0 | 4.5 | 4.5 |
| Lightweight | 5.0 | 3.5 | 4.5 | 3.5 | 3.5 |
| Durable | 4.5 | 4.0 | 4.0 | 4.0 | 5.0 |
| Fight water retention | 5.0 | 3.5 | 3.5 | 4.0 | 5.0 |
| Sturdy mechanism | 5.0 | 5.0 | 4.5 | 4.5 | 4.5 |
| Reliable | 4.5 | 4.0 | 4.0 | 4.5 | 4.0 |
| Fail-safe mechanism | 3.5 | 3.5 | 3.5 | 3.5 | 3.0 |
| No transport of aquatic invasives | 5.0 | 4.0 | 4.0 | 4.0 | 4.5 |
| Water protection | 4.5 | 4.0 | 3.5 | 4.0 | 4.5 |
| | **51.0** | **44.5** | **45.5** | **45.5** | **46.0** |
| **Part II: Mobility** | | | | | |
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
| Fast on/off transition | 5.0 | 4.0 | 4.5 | 4.5 | 3.0 |
| Convenient | 4.0 | 3.5 | 4.0 | 4.0 | 3.0 |
| Freedom of movement | 5.0 | 4.5 | 4.5 | 4.5 | 4.0 |
| Less user-engagement | 4.0 | 3.5 | 4.5 | 4.5 | 3.0 |
| Easy maneuver | 4.5 | 3.5 | 4.0 | 4.0 | 2.5 |
| Cushioning and motion control | 4.5 | 4.0 | 4.5 | 4.5 | 3.5 |
| Easy opening | 4.0 | 3.5 | 4.0 | 3.5 | 3.0 |
| | **31.0** | **26.5** | **30.0** | **29.5** | **22.0** |
| **Part III: Fitting** | | | | | |
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
| Micro-adjustability | 4.5 | 4.5 | 5.0 | 4.5 | 4.0 |
| Snug fit | 4.5 | 5.0 | 5.0 | 5.0 | 4.0 |
| Custom fit comfort | 4.0 | 4.5 | 5.0 | 5.0 | 4.0 |
| No pressure points | 3.5 | 3.5 | 4.0 | 4.0 | 4.0 |
| | **16.5** | **17.5** | **19.0** | **18.5** | **16.0** |
| **Part IV: General** | | | | | |
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
| Most innovative | 4.5 | 5.0 | 4.0 | 3.5 | 2.5 |
| Diverse area of applications | 4.0 | 4.5 | 4.5 | 4.0 | 3.0 |
| Commercial stand-point | 5.0 | 5.0 | 5.0 | 5.0 | 3.0 |
| Easy maintenance | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 |
| | **16.5** | **17.5** | **16.5** | **15.5** | **12.5** |
| **Weighted Average** | | | | | |
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
| Protection | 51.0 | 44.5 | 45.5 | 45.5 | 46.0 |
| Mobility | 31.0 | 26.5 | 30.0 | 29.5 | 22.0 |
| Fitting | 16.5 | 17.5 | 19.0 | 18.5 | 16.0 |
| General | 16.5 | 17.5 | 16.5 | 15.5 | 12.5 |
| | **30.5** | **27.8** | **29.4** | **28.9** | **25.8** |

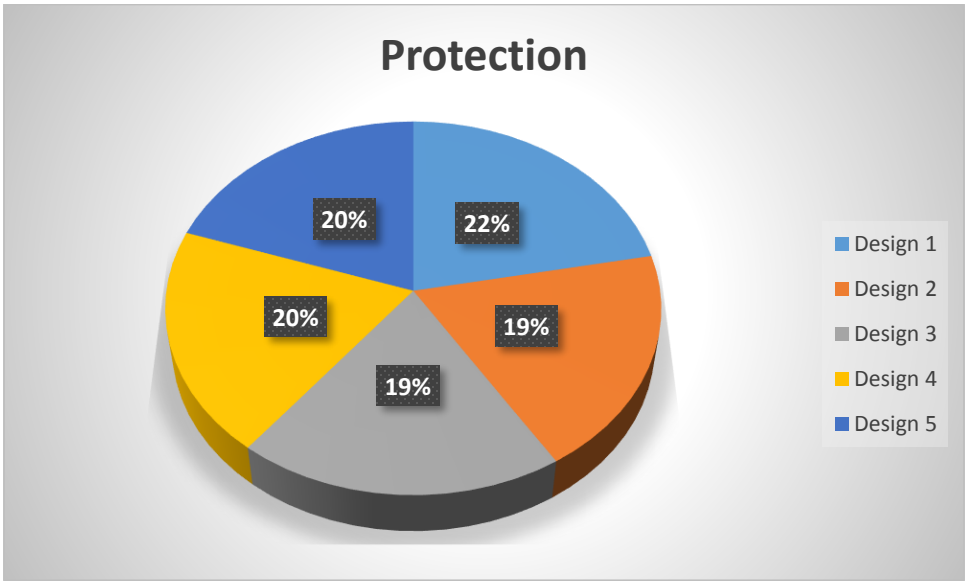


Figure 32: Pie chart showing average design ratings related to footwear protection

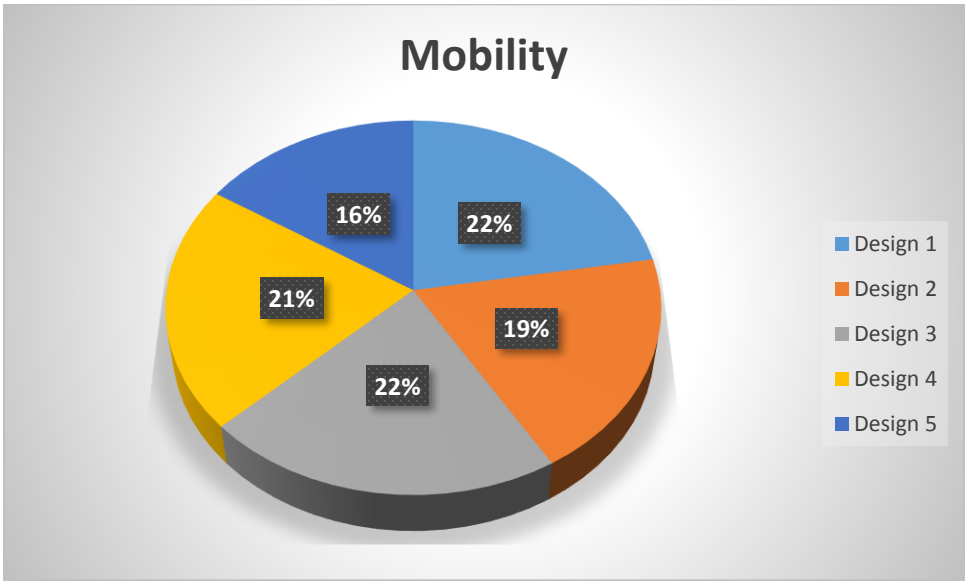


Figure 33: Pie chart showing average design ratings related to footwear mobility

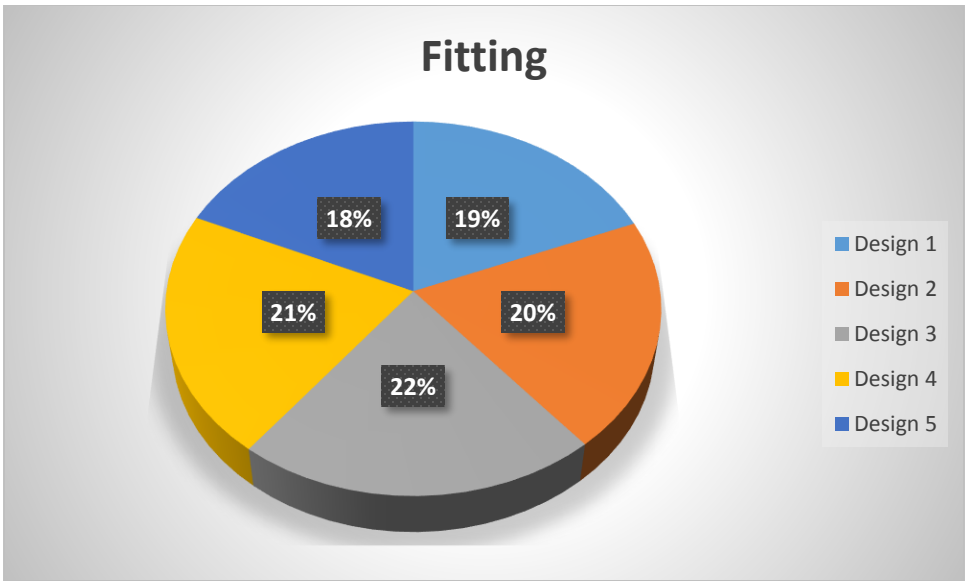



Figure 34: Pie chart showing average design ratings related to footwear fitting

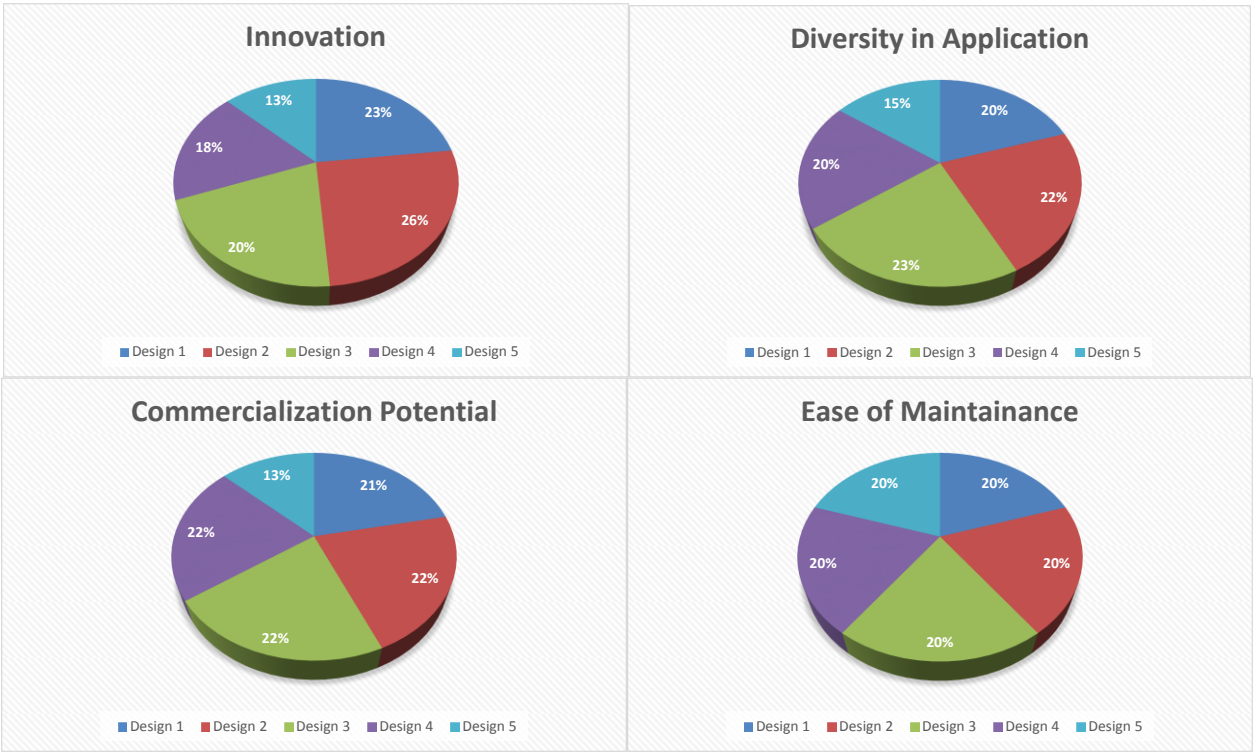



Figure 35: Pie charts showing average design ratings related to various miscellaneous parameters

Based on the analysis, it can be seen that each of the five designs has its own merits and demerits. For a single design selection, a weighted average calculation is needed, where certain design criteria most suited to our design targets are weighed more than others. Weighting the selection criteria can often provide an extra level of discrimination when making decisions through Pugh analysis. It can also provide a form of "robustness" assessment (Burge, 2009). In the previous chapters, the need for protection, fit and mobility, have been emphasized in fishing footwear. Hence, these three parameters have been provided equal weights. However, the parameters associated with general characteristics, such as commercialization or ease of maintenance, are assigned lower weights. Table 8 provides the assigned weights to various design parameters from heuristic viewpoint. The protection, mobility and fit are provided high weight percentage of 28.57%. The four parameters in the general design category are provided a percentage weight of 3.6% each.

Table 8: Assigned weights to various design parameters

| Criterion | Weightage Factor | Weight Percentage |
|---|---|---|
| Protection | 2 | 28.57% |
| Mobility | 2 | 28.57% |
| Fit | 2 | 28.57% |
| Innovation | 0.25 | 3.57% |
| Diversity in Application | 0.25 | 3.57% |
| Commercial Standpoint | 0.25 | 3.57% |
| Easy Maintenance | 0.25 | 3.57% |
| Total | 7 | 100.00% |

The formula for evaluating overall weighted mean average is given by the following expression where the total point in each category is multiplied by its weightage factor to obtain a weighted sum, which is thereafter divided by the sum of weights (Burge, 2009).

$$W_{avg} = \frac{\sum weight \times point}{\sum weight}$$

The overall weighted average is given in the last section of Table 7 and has been shown visually in Figure 36. Design-1 is found to be a preferred design with the maximum weighted average points among all the design, with a value of 30.5 points. The pie chart shows a maximum percentage value (21.4%) for this design. This is followed by Design-3, having a clear benefit in the "fit" criterion as discussed above, with a weighted average value of 29.4 points.

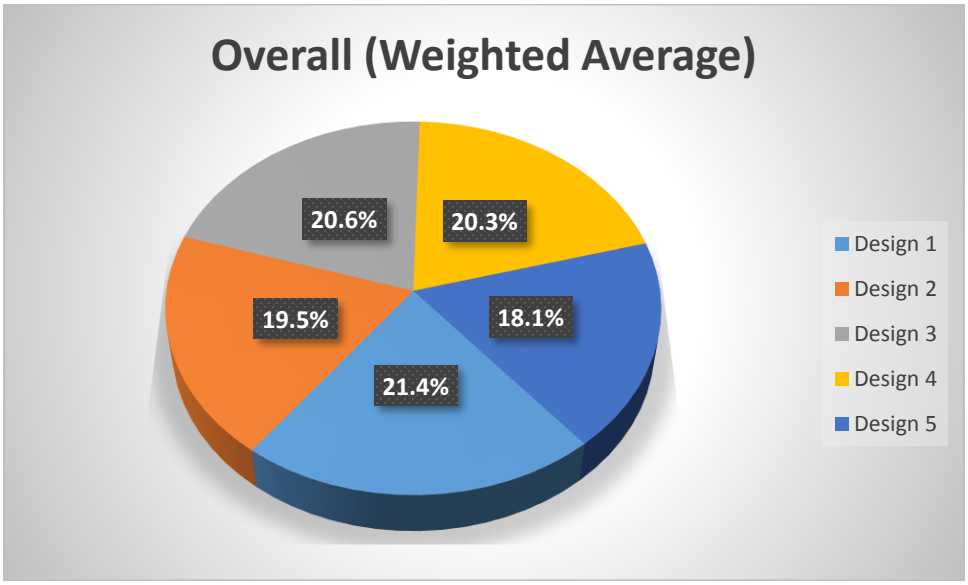



Figure 36: Pie chart showing overall weighted average design rating related to all parameters

Henceforth, based on the expert review, Design-1 was selected as the preferred design in this research study. In the next chapter, the foundation of concept Design-1 has been used to built upon and go forward with a detailed design and evaluation for this design.

CHAPTER VI

# Concept Detailing and Evaluation

In this chapter, the shortlisted design concept is refined and detailed on the basis of inputs from the expert reviewers. This chapter showcases the integration of all parts into the final configuration of the product. Various illustrations provide definitive whole-product layouts that identify the form of each component, each commencing work on the general arrangement and major assembly manufacturing drawings. After the design-detailing process, entails the final evaluation and validation of the design through the use of decision grid feedback by expert reviewers.

## The Concept Detailing process (Stage IV)

The detail design phase lies between the concept design and manufacturing phases of the design process; it is principally concerned with the process of transforming a product concept into a set of manufacturing drawings and documentation (Milton & Rodgers, 2011). It should be noted that, as the design process is an iterative one, there are no neat demarcations between the sequential phases and, in reality, many of the activities will overlap or be undertaken in parallel. These are used to develop and confirm understanding of form, fit, and function at a detailed level. This helps the client and designers understand how all the parts need to work together to make a reliably functioning product. Detail design, or design-for-manufacture, is the stage wherein the necessary engineering is done for every component of the product. During this phase, each part was identified and engineered. Tolerances, materials, and finishes were defined, and the design was documented with drawings or computer files (Riley, n.d.). Many basic “design for manufacturability” attributes were also refined and confirmed through this early

prototyping. Three-dimensional computer models form the core of today's rapid prototyping and rapid manufacturing technologies. During this phase, 2D and 3D projection models were developed for each part of the product taking into account, aesthetics/finishing, tolerances, materials, manufacturing considerations, simplicity, ease of assembly, ease of maintenance, intuitive operation involving few steps, etc. An "appearance model" is a full-scale, non-functional representation that looks identical to the prospective new product (Riley, n.d.). Two and three-dimensional software packages are used to make such detailed models.

In the previous chapter, in light of the survey results by Pugh analysis, Design-1 was selected for detailing to perform the final assessment (see Figure 38). Each part of the fastening system of the fishing boot is refined for documentation and reflecting the manufacturing prototypes.

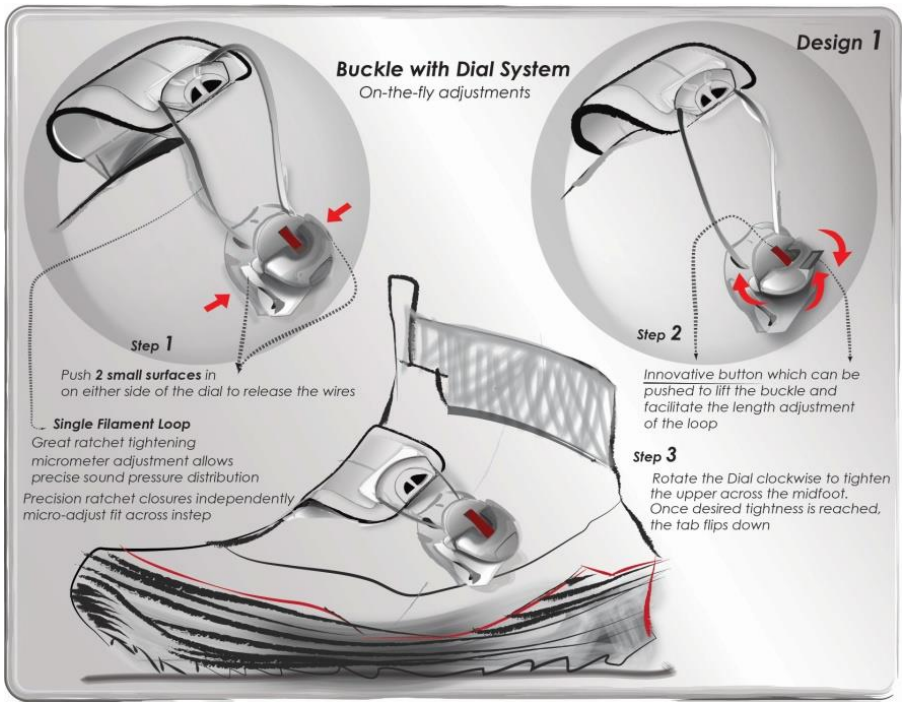



Figure 37: Winner Concept - Design 1

The proposed boot has a buckle with dial fastening system which comprises of four major parts:

1. Buckle-Dial fastener on the outside of the boot (see Figure 40 and Figure 41)
2. Thermo-formed EVA padded strap on central position of the instep (see Figure 43)
3. Ratchet strap on the inside of the boot (see Figure 42)
4. Micrometric Ratchet Closure on the inside of the boot (see Figure 39 and Figure 41)


Figure 38: Detailed Design - Full View of the Boot (right foot)

As mentioned earlier, protection is paramount for fishing shoes and this model does great in this respect. The upper and sole were made of molded rubber that offer significant resistance towards rough terrains such as rocky river beds or shores, so that anglers do not have to deal with

unpleasant mishaps. The soles were also designed to protect the toes and the sides of the feet. Waterproof materials featured in the upper provided protection in wet conditions; while the sealed seams onto the molded toe covering ensured that no water/dirt/debris or invasive species can enter the boot. Angler's feet still remain mobile and flexible, and they do not have to worry about accidents. The large back loop of the boot helps easy foot insertion.


Figure 39: Detailed Design - Inner Face (right foot)

The soft instep strap is adjustable from both sides, to perfectly center the EVA pad over a high or low instep (see Figure 40). The system eliminates any uneven pressure across the foot, especially in arch area.

Highlighted features of wide, soft, thermo-foamed EVA padded strap include:

- Increased cushioning and comfort.
- Distributes pressure evenly over the arch area.
- Adjustable from both sides for perfect centering.


Figure 40: Detailed Design - Outer Strap

The adjustable buckle-dial mechanism goes around the instep arch and one can use the dial and ratchet buckle system to customize the shoes as needed. Making them tighter will help avoid debris from gathering inside. The instruction manual of the fastening system was illustrated above (see Figure 41). It enables the user to simply turn the dial, which tightens the wires to form a comfortably stable envelope around the foot. The boot will obtain its perfect fit, and never loosen or become untied.

To remove, the user would simply pinch both side small surfaces around the dial and the cables instantly release (see Figure 41). For significantly bigger length adjustments, there is an innovative red button which can be pushed to lift the buckle and adjustments could be made easy. The red button releases the ratchet lever making adjustment. Lifting up the buckle flap then adjusts the fit along the entire length of the shoe, adapting the upper to the shape of the foot for a customized fit.

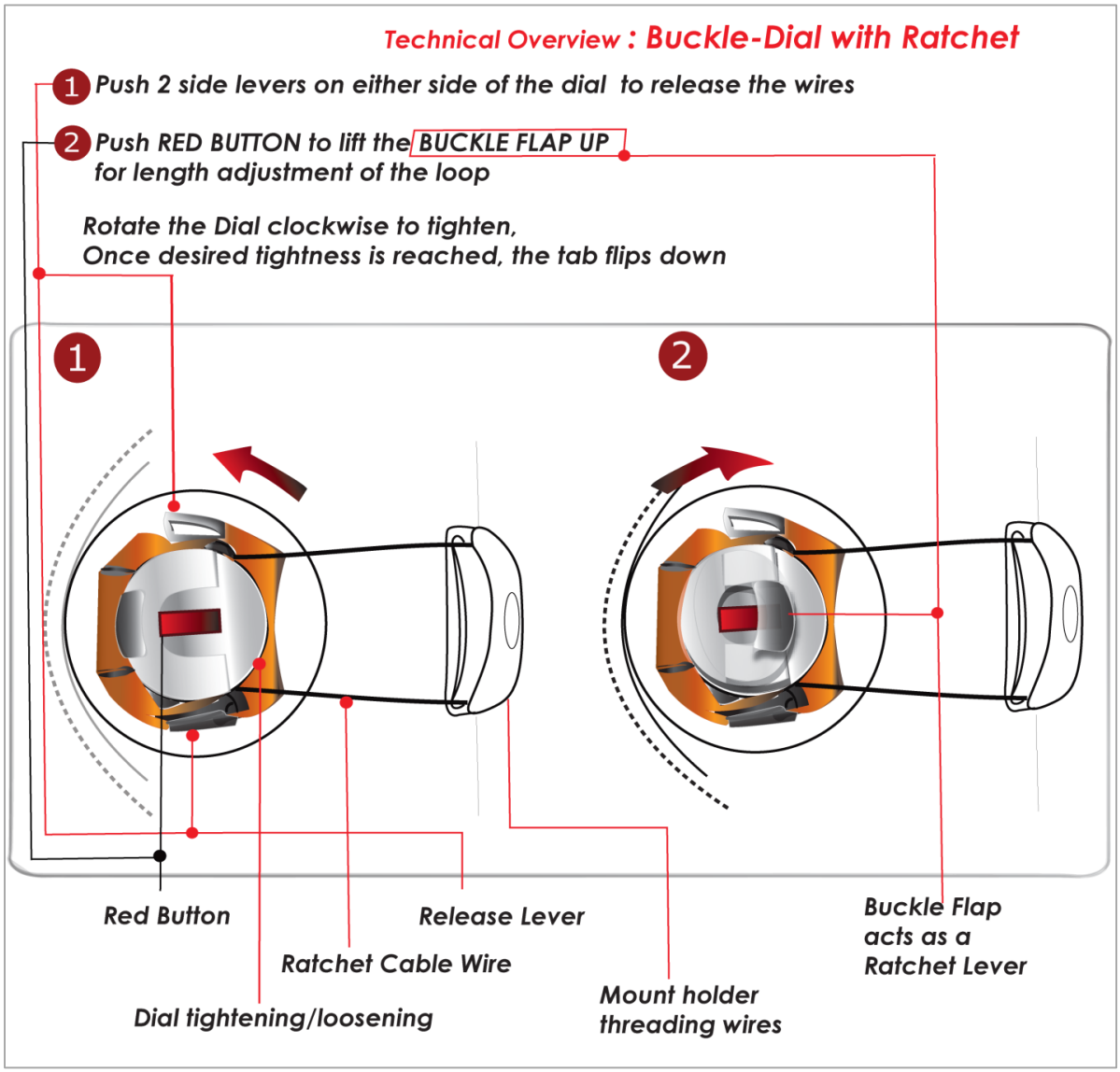



Figure 41: Detailed Design - Buckle-Dial Mechanism

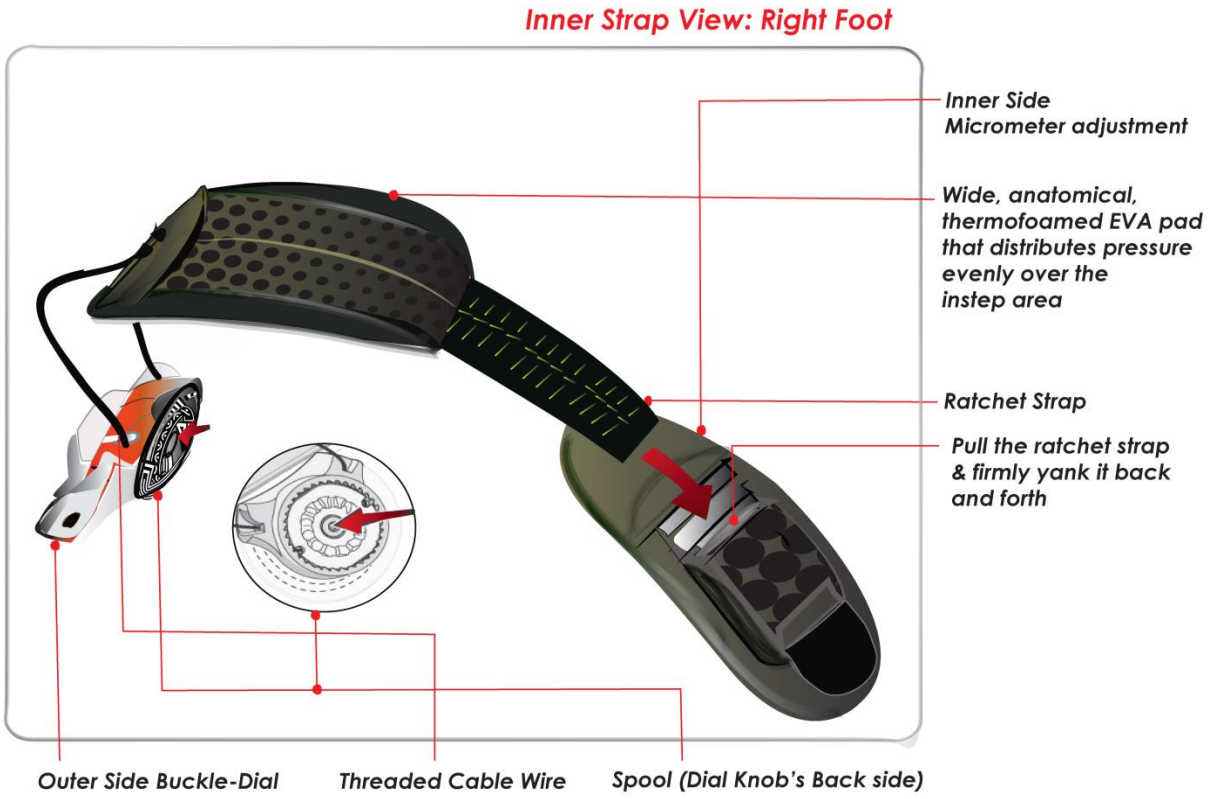



Figure 42: Detailed Design - Inner Strap

A simple ratchet closure system is on the inside to make adjustments for placing the instep strap at the center and distributing even pressure throughout the foot (see Figure 42). This is an improvement from the previously proposed concept sketch. The iteration was made due to the perceived importance of flexible adjustments from both sides of the foot for perfect centering. This also distributes the pressure evenly over the arch area and avoids the formation of any pressure points (see Figure 43). The ratcheted adjustments are placed at short increments, offering an impressive degree of adjustment and allowing precise sound pressure distribution across the instep area. The mechanism is described as “micro metric” – an accurate enough description.

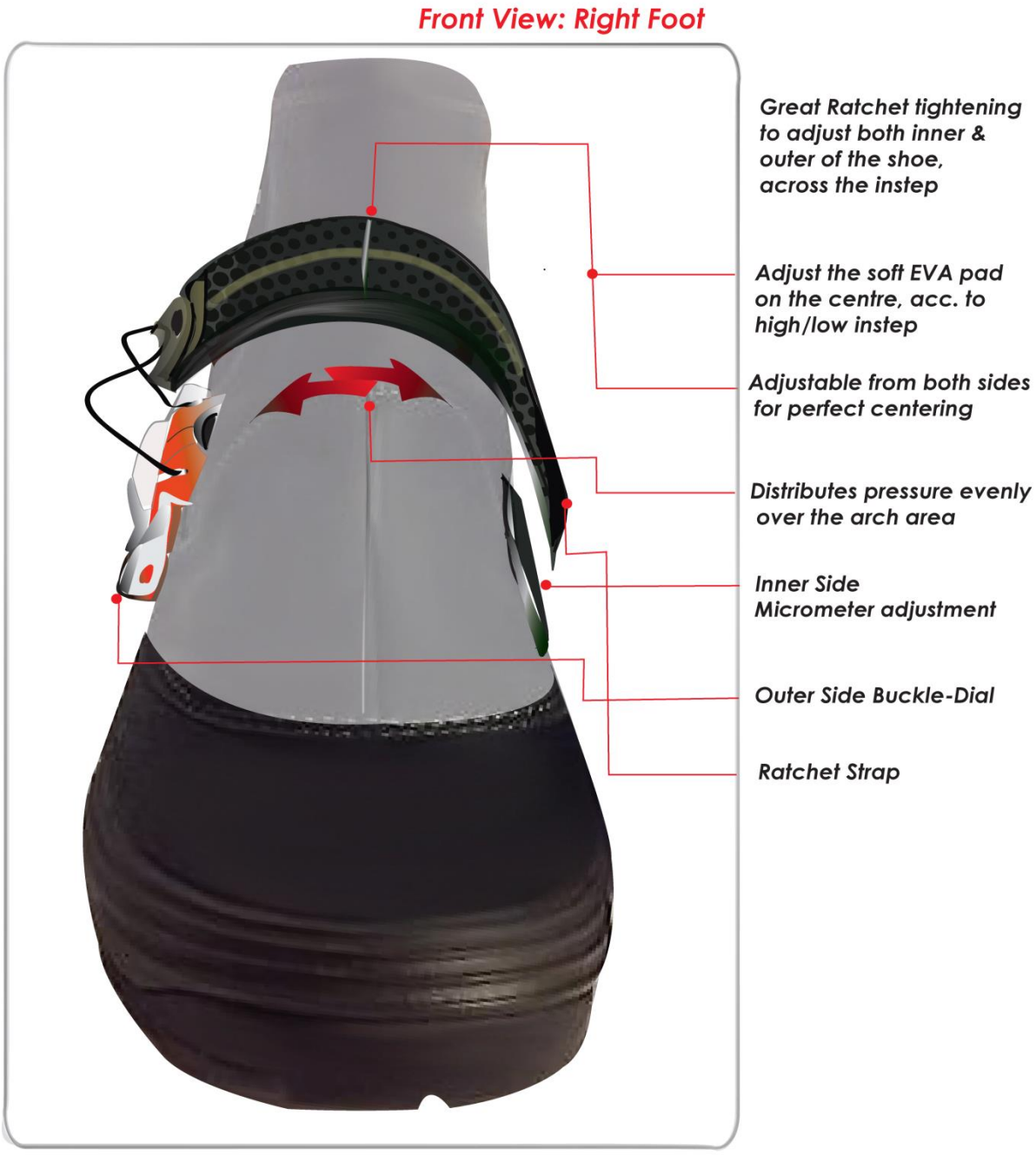



Figure 43: Detailed Design - Front View

**Evaluation (Stage V)**

The evaluation of design concepts implies and involves both comparison and decision making (Miller & Morris, 1999). As a comparative score analysis was done previously to select one among five proposed concepts, our final level of evaluation is by the decision grid. This is basically similar to "Go/No-Go Screening" as a step of validation before manufacturing (Burge, 2009). The first step was to return to the set of performance requirements developed during the early stages of design development. Thereafter, each consolidated performance requirement was transformed into a yes/no question. Each question could be answered as yes, no, or maybe. If the majority of answers are "yes" or "maybe", then the concept is a "Go" for physical prototyping; if the answer is "no", then the concept is a "No-Go". While a single "no" response is not enough to exclude a concept, it does mean that the concept may require re-examination. The expected outcome is a validated choice from a group of reviewers in case of a go/no-go-decision, and a better understanding of what aspects need improvement/optimization. In this step, the reviewers assess detailed design concept with technical illustrations to determine its solution potential.

***Instrumentation***

An emailed questionnaire with various constructs for measuring performance features: protection, fitting, mobility and general requirements, similar to the previous instrument utilized in "Concept Screening" step. The opinion rating is taken using three selective options – "Yes", "Maybe" and "No", signifying a positive, neutral or negative decision and/or opinion corresponding to each performance criterion. Performance criteria have been selectively consolidated into 10 primary features with a blend of all parameters of protection, fitting,

mobility and general requirements. In addition, space has been provided for additional feedback and/or comments on the selected design. The instrumentation has been provided in Appendix C.

***Population***

The population involves five human subjects – including previous two reviewers (A1 and A2) from concept screening stage and three new reviewers. The new evaluators were contacted through our previous experts who agreed to participate in the study for a stronger validation and population-bias control. In order to protect their identity, the new reviewers have referred as B1, B2 and B3. All of the evaluators have sound technical-design knowledge in the outdoor sports category, and also pursue fishing as their hobby.

***Data Analysis***

Table 9 shows the consolidated responses of different reviewers. The first three performance specifications – Secure and sturdy mechanism, fighting water retention and no transport of aquatic invasive, pertains to protection requirements of the presented fastening concept. Majority of reviewers had validated positively with the protection attributes of the Buckle with dial concept in each of the performance criterion. However, Reviewer A2 was not sure if the concept is secure and sturdy enough to sustain rough environment and harsh submarines. It could be a check-point for doing the test trial of the product, while exposed to extreme conditions of cold, deep water, rocky terrains, etc. Fighting water retention and aquatic invasive is supported with majority of positive responses. This could be anticipated due to the usage of highly protective, insulated and waterproof materials in upper, sole and fastening mechanism of the boot. Also, there was hardly any trim which has loose ends in the closure mechanism.

Table 9: Reviewer Responses towards the Decision Matrix

| Decision Matrix | | | | | |
|---|---|---|---|---|---|
| **Performance Assessment Criterion** | **A1** | **A2** | **B1** | **B2** | **B3** |
| **Secure & Sturdy mechanism** | YES | NO | YES | MAYBE | YES |
| **Fight water retention** | YES | YES | MAYBE | YES | YES |
| **No transport of aquatic invasives** | YES | YES | YES | MAYBE | MAYBE |
| **Fast on/off transition** | YES | NO | YES | MAYBE | YES |
| **Convenient & Easy opening** | YES | YES | NO | YES | YES |
| **Less user-engagement** | NO | MAYBE | YES | YES | YES |
| **Micro-adjustability** | YES | YES | YES | YES | YES |
| **No pressure points** | YES | MAYBE | YES | MAYBE | YES |
| **Diverse area of applications** | YES | YES | MAYBE | YES | YES |
| **Commercial stand-point** | MAYBE | YES | YES | MAYBE | YES |

The next three performance requirements includes fast on/off transition, convenient/easy opening and less user-engagement, which attributes to mobility features of fishing boot. While majority gave a “go” decision in these specifications, Reviewer A2 has responded “no” for a quick transitioning mechanism. The probable cause of a negative response could be adjustment of closure at both sides of the boot by buckle-dial on the outside and ratchet on the inside. Again, there is a provision of adjusting the boot on just the outer side buckle-dial fastener with a push of red button to release or a rotation of dial to tighten, while fixing the ratchet just one time at the beginning. Both sides adjustment is not a requirement in this case, but an additional feature for those with unusually high/low instep for customized fit and sound pressure distribution. In all

probability, Reviewer B1 has responded “no” for convenient/easy opening for the same judgment.

“Micro-adjustability” and “no pressure points” are performance specifications for fit parameters of the fishing boot. These points continue to be strong and strongly validated with majority of positive responses. Obviously, the concept showcases micro-adjustability as its unique selling point, through its micro-metric ratchet and turn of dial, allowing for precise, incremental tightening and loosening of the closure.

General specifications included criteria like diverse area of applications and commercial stand-point. Reviewers had mostly validated this concept as a widely suitable application for other sports and the details of design may have increased its potential for commercial use.

To determine if the final design is evaluated as a “go” or “no-go” by market experts and make an assessment towards the degree of affirmation or negation, a final evaluation metric is calculated. This metric denotes a single quantitative number which represents the ultimate evaluation criteria. This evaluation is given in Table 10. A point value of 1 is provided for an “Yes” answer, 0 for a “Maybe” and -1 for a “No” answer. This approach provides a clear demarcation between negative and positive responses, in a literal sense. As discussed earlier, certain weightages are allotted to assessment criteria based on how important a criterion is for this research. Protection, mobility and fit parameters are all given an equally high weightage of 1.0, whereas other parameters (such as commercialization potential) are provided lower weightage of 0.5, as shown in the table. A total is evaluated corresponding to each row. The minimum points possible corresponds to a case where all reviewers in the study provide a “No” answer to a particular criterion. Similarly, the maximum corresponds to all “Yes” answers.

Table 10: Evaluation of Final Decision Metric

| Decision Matrix | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Performance Assessment Criterion** | **Weight** | **A1** | **A2** | **B1** | **B2** | **B3** | **Total** | **Min.** | **Max.** |
| ***Protection*** | | | | | | | | | |
| **Secure & Sturdy mechanism** | **1.0** | 1 | -1 | 1 | 0 | 1 | **2** | -5 | 5 |
| **Fight water retention** | **1.0** | 1 | 1 | 0 | 1 | 1 | **4** | -5 | 5 |
| **No transport of aquatic invasives** | **1.0** | 1 | 1 | 1 | 0 | 0 | **3** | -5 | 5 |
| ***Mobility*** | | | | | | | | | |
| **Fast on/off transition** | **1.0** | 1 | -1 | 1 | 0 | 1 | **2** | -5 | 5 |
| **Convenient & Easy opening** | **1.0** | 1 | 1 | -1 | 1 | 1 | **3** | -5 | 5 |
| **Less user-engagement** | **1.0** | -1 | 0 | 1 | 1 | 1 | **2** | -5 | 5 |
| ***Fit*** | | | | | | | | | |
| **Micro-adjustability** | **1.0** | 1 | 1 | 1 | 1 | 1 | **5** | -5 | 5 |
| **No pressure points** | **1.0** | 1 | 0 | 1 | 0 | 1 | **3** | -5 | 5 |
| ***General*** | | | | | | | | | |
| **Diverse area of applications** | **0.5** | 1 | 1 | 0 | 1 | 1 | **4** | -5 | 5 |
| **Commercial stand-point** | **0.5** | 0 | 1 | 1 | 0 | 1 | **3** | -5 | 5 |
| **Weighted Sum** | | | | | | | **27.5** | **-45** | **45** |
| **Normalized Weighted Sum** | | | | | | | **0.61** | **-1** | **1** |

A weighted sum is evaluated, based on the weight formula discussed in previous chapter, corresponding to the reviewer total points, minimum and maximum possible points. These numbers are 27.5, -45 and 45 respectively. A qualitative significance can be obtained if the weighted sum (27.5) is scaled back to a value between -1 (complete No) and +1 (complete Yes). This is done by normalizing the weighted sum using the following equation.

$$Normalized\ Weighted\ Value = \frac{Weighted\ Value}{Maximum\ Weighted\ Value}$$

This gives a normalized weighted sum of 0.61, which serves as the final decision metric for our detailed design work. This is pictorially shown in Figure 44. This signifies that the developed design is considered statistically positive and agreed upon by the experts.

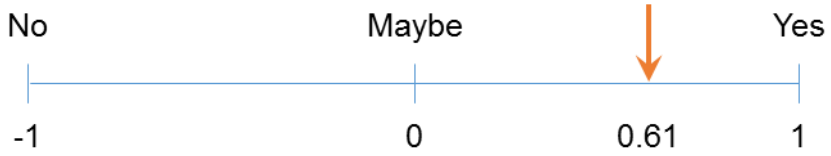



Figure 44: Pictorial Representation of Final Decision Metric

This may also signify that 61% of the experts would agree with the design creating positive value with respect to our major design parameters of protection, fit and mobility and some minor factors such as commercial value and diversity in application.

CHAPTER VII

# Conclusion, Potential Applications and Future Research

In this chapter the conclusion of this thesis and the research results are presented together with outlines for further work. In addition, an extended application of the shortlisted design solution in other outdoor gears is illustrated for demonstrating its generic utilitarian significance.

## Conclusion

The goal of this research was to propose a design for a novel, utilitarian fastening concept in fishing footwear, which is conceptualized to offer optimum protection, fit and mobility to anglers. Hence, the aim of the thesis was focused at the conceptual development of a fastening system in a functional product; fishing footwear - by assimilating utilitarian-design values in a product-design model. This was achieved through project-based research methodology; utilizing different stages of iterative design process, enhancing the knowledge about product, different closure systems, design task and/or design alternatives. The study has been carried out within four different focus areas -

- Understand the functioning requirements of fishing footwear closure systems
- Identify design issues through user reviews and market research reports
- Find a conceptual design-solution through innovative ideations and expert selection
- Transform the product concept into a design-for-manufacturability prototype

As part of planning phase, an extensive review was conducted to establish a need for research around fastening systems for fishing footwear. This involved review of conventional fastening systems commonly used within footwear domain and identified limitations in context of fishing footwear. The literature review of various types of fishing footwear for different

terrains and environmental conditions helped clarify the functioning requirements of the product. A thorough investigative study was conducted as part of research phase involving elaborate market reviews, hands-on test findings, analysis of various shoe closures and existing technologies, including shoelace technology, athletic shoelace specialized system. Through market research findings, a niche within innovative fastening gear in fishing footwear was identified, which conforms to the performance needs of protection, mobility and fit. As mentioned by one of our expert reviewers, “the footwear industry has for too long not been innovative enough and daring enough to take risk in design. The traditional lacing systems have not evolved as other industries have in the development of technical ideas, especially in fishing sports”.

Based on above study, five illustrative design concepts for fishing footwear fastening systems were created based on ideations process entailing common hold fastening concepts, such as helmets, car seats, integrated gravel guards in apparels, etc. The proposals are presented with detailed conceptual sketches and elaboration on the conceptual idea. As part of concept evaluation phase, one fastening concept was selected using feedback from footwear design experts. The instrument involved for such feedback was developed in the form of a questionnaire which emphasized a utilitarian and retail perspective for the proposed design concepts. Concept Design-1, utilizing a Buckle with Dial system, scored the highest ranking among all, with maximum percentage value of 21.4%. This is followed by Design-3, using a Dial Tightening system, was a runner-up having a clear benefit in the “fit” criterion.

Once the design process has been carried out at a highly conceptual level, the "winning" concept is detailed. The selected fastening concept was refined and detailed as part of concept

detailing phase. An intricate 3-D model of the shoe along with individual fastening components and a detailed technical specification/instruction sheet were developed adherent to design standards used in the footwear industry. Furthermore, this phase entails the final-design performance assessment where verification of the final design solution was based on decision matrix technique. This yielded an approval rate of +0.61 between a scale of -1 (depicting complete "no") to +1 (complete "yes").

Overall, an approved solution for fishing footwear fastening needs was created using this study. One of the reviewers stated that, "it could be a great solution for surf fishing, could also have some potential for commercial (long liners, blue fin fishermen, sine netters)".

**Other Potential Applications**

The fastening system is tailored toward fishing footwear and other associated shoes, but the concepts discussed can be translated into any realm of product design or outdoor sports. Design concepts serve as a baseline tool to support future design and research efforts relevant to a given situation (McCullough, 2010). The conceptual development could be theoretically used in inter disciplinary contexts for future development of other functional wearable products.

When designing a fastening concept the aspects of safety, comfort and usability are important. An introductory thought has been put into the extended application of the shortlisted fastening concept in other outdoor gears. This helps us to see the light of potential utilitarian values of this innovative concept evolved through this research. Additionally, it gives us a glimpse of possible future research endeavors, which may be investigated and explored further. The findings of this study could be put into application in other significant utility products like bag packs, helmets, sports equipment, etc. (see Figure 45, Figure 46 and Figure 47).

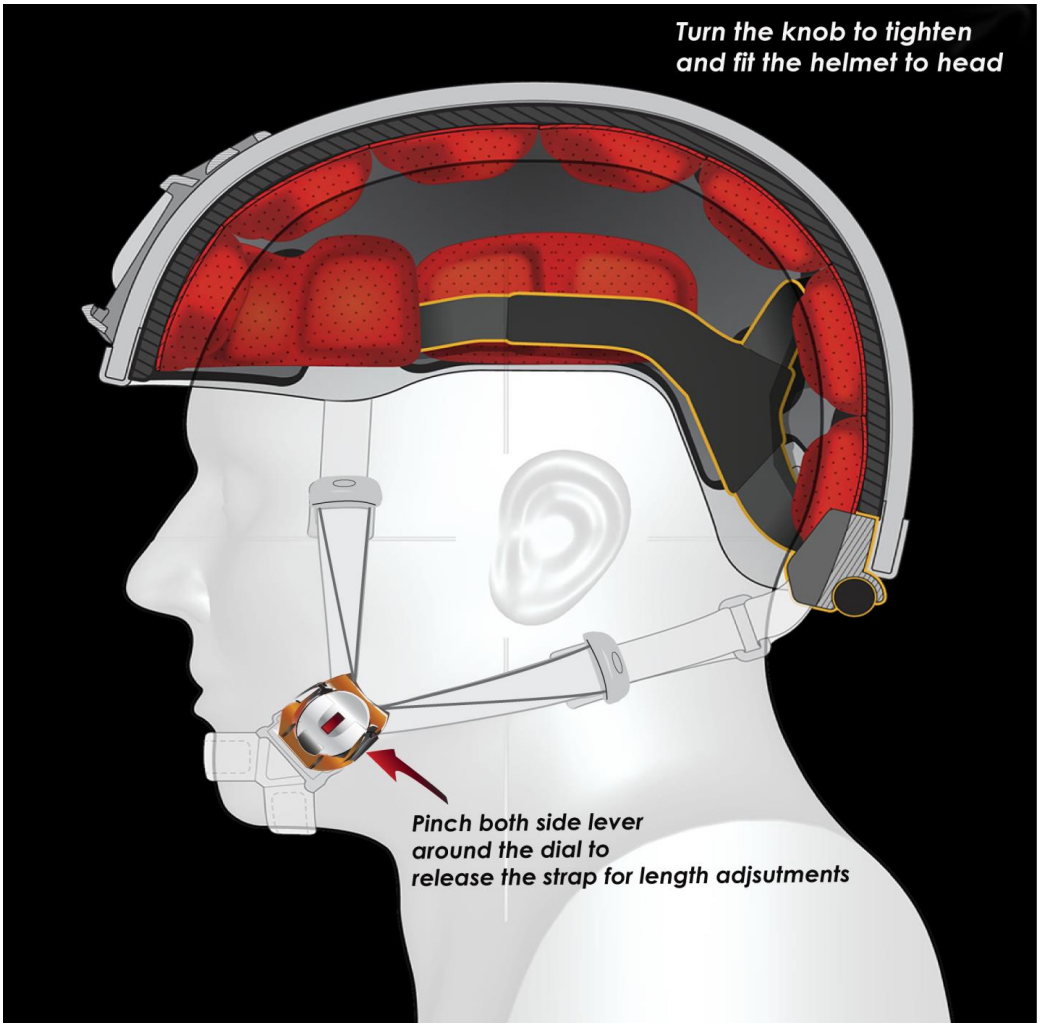



Figure 45: Final concept utilized in Helmet

The final concept, using a Buckle with Dial system is utilized in the above helmet product. It is specially designed for bi-cycle helmets, where quick fixation system is one of the most important attributes. The Dial acts as an incremental tightening/loosening device, which fixes the strap length through its wire cable (see Figure 45). The cyclists can release the wires by pinching both side levers around the dial, which can completely loosen of the strap to remove the gear from their head.

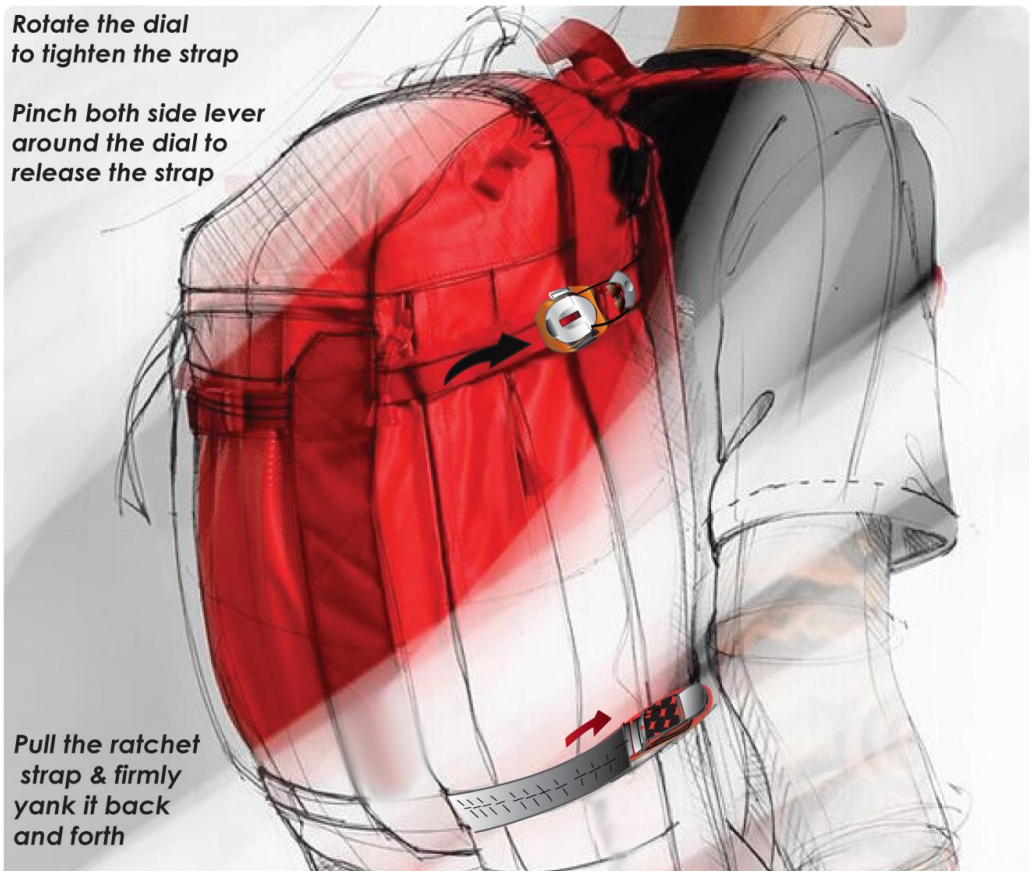


Figure 46: Final concept utilized in Bag pack

In the above bag pack, buckle with dial concept is utilized along with ratchet snap mechanism (see Figure 46). One of the higher side straps could use the dial system for easy transitional opening of the partial bag, in case of immediate pull of things from inside of the bag. Whereas, the lower side strap utilizes a simple ratchet strap system for one-time lock adjustment before the travel/activity and then it could be opened whenever needed later. The user needs to pull the ratchet strap and firmly yank it back and forth for correct adjustment of the length of strap.

Above product illustrated is an elbow pad meant for use during sports activity. Based on the application (usage), it is safe to assume that easy adjustments, custom-fit, comfort and protection must be top priority of these products. Thereby, a buckle with dial system is utilized

for such need adherence, where one could tighten the pad with a turn of dial and achieve a perfect fit, as desired. Similar to shoes, elbow pads are also those products which are close in contact with the human body, unlike bag-packs or other outdoor gears. Thus, eliminating any pressure points over the skin is essential. This is particularly addressed by placement of double strap all around the arm, for providing both sides adjustment, enabling even pressure distribution.


Figure 47: Final concept utilized in Elbow Pads

Finally through testing, adjusting, modifying, and re-testing the prototype(s), the prototype(s) may be optimized in order to be more efficient, cost effective, and desirable with competitive advantages within the market.

It is important to note that the utilized design methodologies help select potentially innovative products, but it is not until after a product has been marketed that innovation can be

assessed. Furthermore, the functionality and manufacturability of a product concept cannot be fully determined before its development.

# GLOSSARY

*Angler-Fisherman* – A person who fishes with a hook and line.

*Comfort* – The harmonious state between human and environment in physiological, psychological, and physical aspects, and can be measured objectively and subjectively for research purposes (Slater, 1985). A state of comfort varies from person to person but is measurement through various techniques.

*Conceptual Design* – A description of the proposed system in terms of a set of integrated ideas and concepts about what it should do, behave, and look like, that will be understandable by the users in the manner intended.

*Design process* – A step-by-step problem-solving approach that designers use to create design concepts and solutions.

*EVA* – Ethylene vinyl acetate (EVA) is similar to rubber, which has "rubber-like" in softness and flexibility, and is resistant to cracks and ultraviolet radiation.

*Functional gear* – Product that is designed to meet specific functional purpose as well as psychological and aesthetic needs of potential users (Tan, Crown, & Capajack, 1998)

*Functional gear design process* – A more holistic approach to creating functional product for potential users. The process is based on steps to explore the design problem, identify critical factors and design criteria, and subsequently develop the design solution and evaluate the design to complete the design process (Orlando, 1979).

*Functional fit* – Ease allowance necessary for movement to perform the required activities. This depends on the mechanism of the fastening system.

*Gauge* – Measuring instrument

*Gaiter* – An extension to boot for covering the ankle and lower leg.

*Gravel Guard* – Type of stocking to protect the foot with wader booties from sand, gravel, and other debris.

*Instep* – The part of a foot's between the ball and the ankle.

*Mid-foot* – One of three regions of the human foot, referring to the area in the middle of the foot. It encompasses the arch of the foot and is composed of bones, tendons and ligaments, connecting the forefoot with the hindfoot.

*Prototype* – Preliminary model of a product, from which other forms are developed or copied.

*Ratchet* – A device consisting of a bar or wheel with a set of angled teeth in which a tooth engages.

*Spool* – A cylindrical device on which thread can be wound; a reel.

*Toe Box* – The toe box is the part of a shoe that covers and protects the toes.

*TPU* – Thermoplastic polyurethane (TPU) is any of a class of polyurethane plastics with many properties, including elasticity, transparency, and resistance to oil, grease and abrasion.

*Thermo-foamed* – Soft foam with insulation properties, which is ideal for a wide range of temperature condition.

*Utilitarian* – Designed to be useful or practical rather than attractive.

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# APPENDIX A: COVER LETTER

West Virginia University
Davis College of Agriculture, Natural Resources and Design

October 18, 2016

Dear Participant,

This letter is a request for you to take part in a research project to design a novel, utilitarian fastening concept in fishing footwear, as a graphic/illustrative model. This research is being conducted by Ruchireeka Rath, pursuant of M.S. in Design and Merchandising at WVU with supervision of Prof. Craig Nelson, an assistant professor in the School of Design and Community Development. Your participation in this project is greatly appreciated and will take approximately 20 minutes to fill out the attached questionnaire. The study is being conducted in partial fulfillment of the requirements for a master's thesis.

The purpose of the study is to hand-select a fastening concept for fishing footwear among various conceptual illustrative designs, from a utility and retail viewpoint, using feedback from various footwear design experts such as yourself. Participation in this research study is completely voluntary and all information you provide will be held as confidential as possible. Your response to the survey is crucial to the success of the study. You may skip any question that you do not wish to answer and you may discontinue at any time. Your job status will not be affected by refusal to participate or by withdrawal from the study.

You will notice a code number assigned with your name in the questionnaire. This code will be used to identify your feedback in my thesis report and to protect your identity in the research thesis. Questionnaire results will be reported in a summary format and individual responses will not be identifiable.

The study had been reviewed and approved by the West Virginia University's Institutional Review Board.

If you have any questions or concerns about completing the questionnaire or about being in this study, you may contact me at rurath@mix.wvu.edu or (304)376-4448. Thank you in advance for your assistance with this research effort. We sincerely appreciate your participation.

Sincerely,

Ruchireeka Rath
Graduate Student
Design & Merchandising

Prof. Craig Nelson
Assistant Professor
Interior Design & Design Studies

School of Design and Community Development

Phone: 304-293-3402
Fax: 304-293-2750

702 Allen Hall
P.O. Box 6124
Morgantown, WV 26506-6124

# APPENDIX B: CONCEPT SELECTION QUESTIONNAIRE

# DESIGN AND EVALUATION OF FUNCTIONAL GEAR FOR PROTECTION, FIT AND MOBILITY-

## Fishing footwear

**Ruchireeka Rath**
Graduate Student
Design & Merchandising
Davis College of Agriculture, Natural Resources and Design
West Virginia University
Morgantown, WV 26506

**Design and Evaluation of Functional Gear for Protection, Fit and Mobility- Fishing Footwear**

Conventional fasteners like laces, cords or elastic can cause difficulties and even danger to the wearer if they come undone during a fishing activity. Among the dangers are slippages of the associated shoe relative to the foot of the wearer and associated instability as well as the tripping danger in the event, if the untied lace is stepped on or becomes tangled. Accordingly, a need exists for an easy-to-use fastening system which securely fastens the shoe while adding minimal bulk, and which is easy to fasten and unfasten by the user. Thus there is a desire and an unmet need to provide shoe closure devices that accomplish the closure mechanism of conventional tie laces in an effective and efficient manner.

This **research aims to create a novel, utilitarian fastening concept in fishing footwear**. Based on investigative study and market research, the solution has been developed through iterative design process to meet the needs of the fishing folks (improving fitting, protection and mobility).

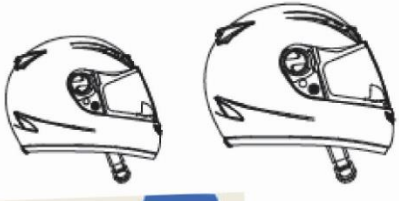
**Instructions**: Using the following 5 point Scale, rate your opinion on each of the following concept of fastening systems in fishing footwear. Please indicate your opinion by giving your rating on the scale of 5 in the box that best correspond to your response:

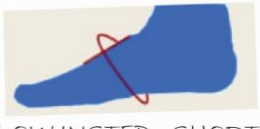
**5 - Extremely effective concept** in providing the performance/meeting the requirements**, 4- Moderately effective concept, 3- Neutral** (similar to traditional concepts)**, 2- Not so effective** and **1** – **Poorly effective concept** (negatively serves the purpose).

**Example:** Read the following statement. Assume that concept 1 functioning is **"Neutral"** and concept 2 is **"Extremely effective"** with the performance **criteria statement**, rate **3** & **5** respectively in the box indicated below.

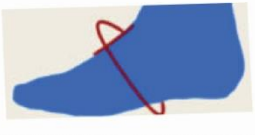
| | |
|---|---|
|  **Concept 1.** Generic Laced closure Fishing footwear |  **Concept 2.** Elastic bungee cord closure Fishing shoe |
| Criteria Statement: **Ease of Use** in fastening | |
| **3** | **5** |

## Inspiration





LOW INSTEP - SHORTER STRAP

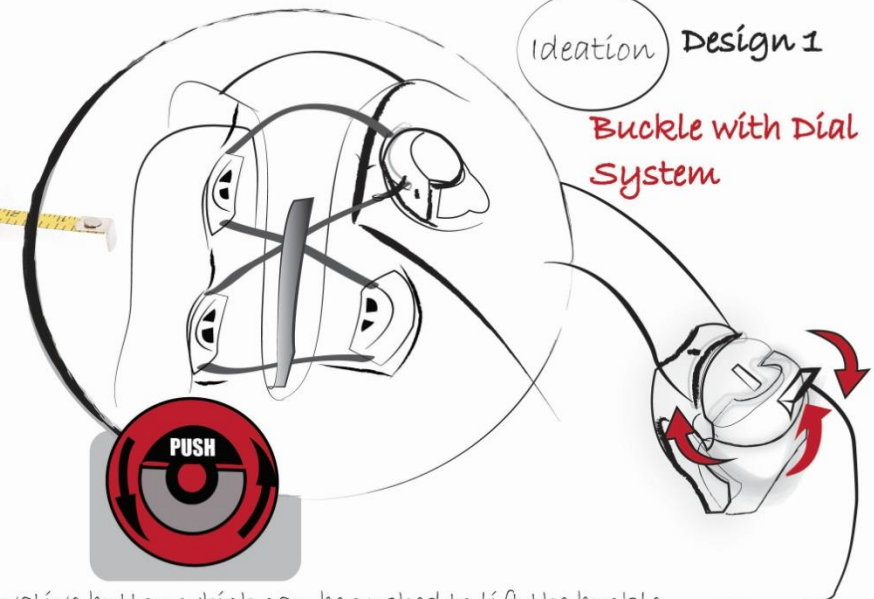


HIGH INSTEP - LONGER STRAP

Ideation

## Design 1

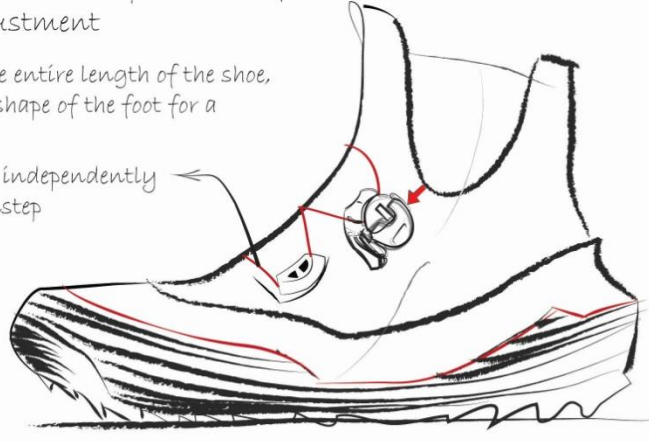
### Buckle with Dial System




Innovative button which can be pushed to lift the buckle and facilitate the adjustment

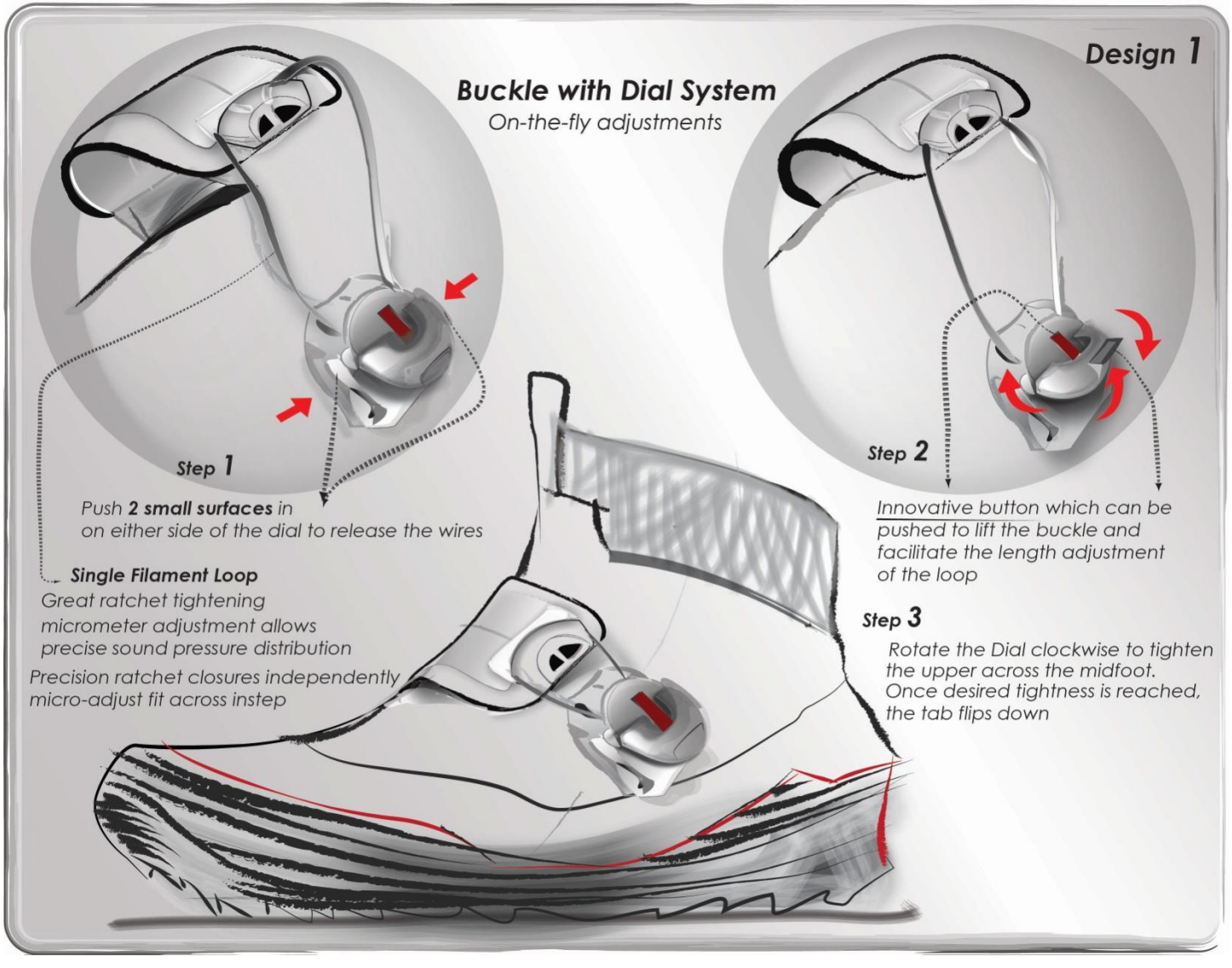
Rotate dial to fit along the entire length of the shoe, adapting the upper to the shape of the foot for a customized fit.

Precision ratchet closures independently micro-adjust fit across instep

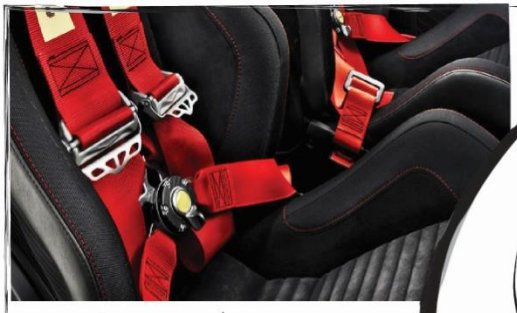


### Adjustable

The main strap can be easily lengthened/ shortened depending on instep height.
This feature allows you to dial in the fit and improve comfort.


Design 1
Buckle with Dial System
On-the-fly adjustments
Step 1
Push 2 small surfaces in on either side of the dial to release the wires
Single Filament Loop
Great ratchet tightening micrometer adjustment allows precise sound pressure distribution
Precision ratchet closures independently micro-adjust fit across instep
Step 2
Innovative button which can be pushed to lift the buckle and facilitate the length adjustment of the loop
Step 3
Rotate the Dial clockwise to tighten the upper across the midfoot. Once desired tightness is reached, the tab flips down

Design 2



Car Seat Harness

Inspiration

Ideation

4 point lock
Magnetic Harness


Rivet holding straps
onto the bottom flaps

Quick release Cam Buckle
Strap slided by each tooth

Magnetic
Touchpoints to join
the bottom



Rubber stripes that
bend and flex with
foot movement

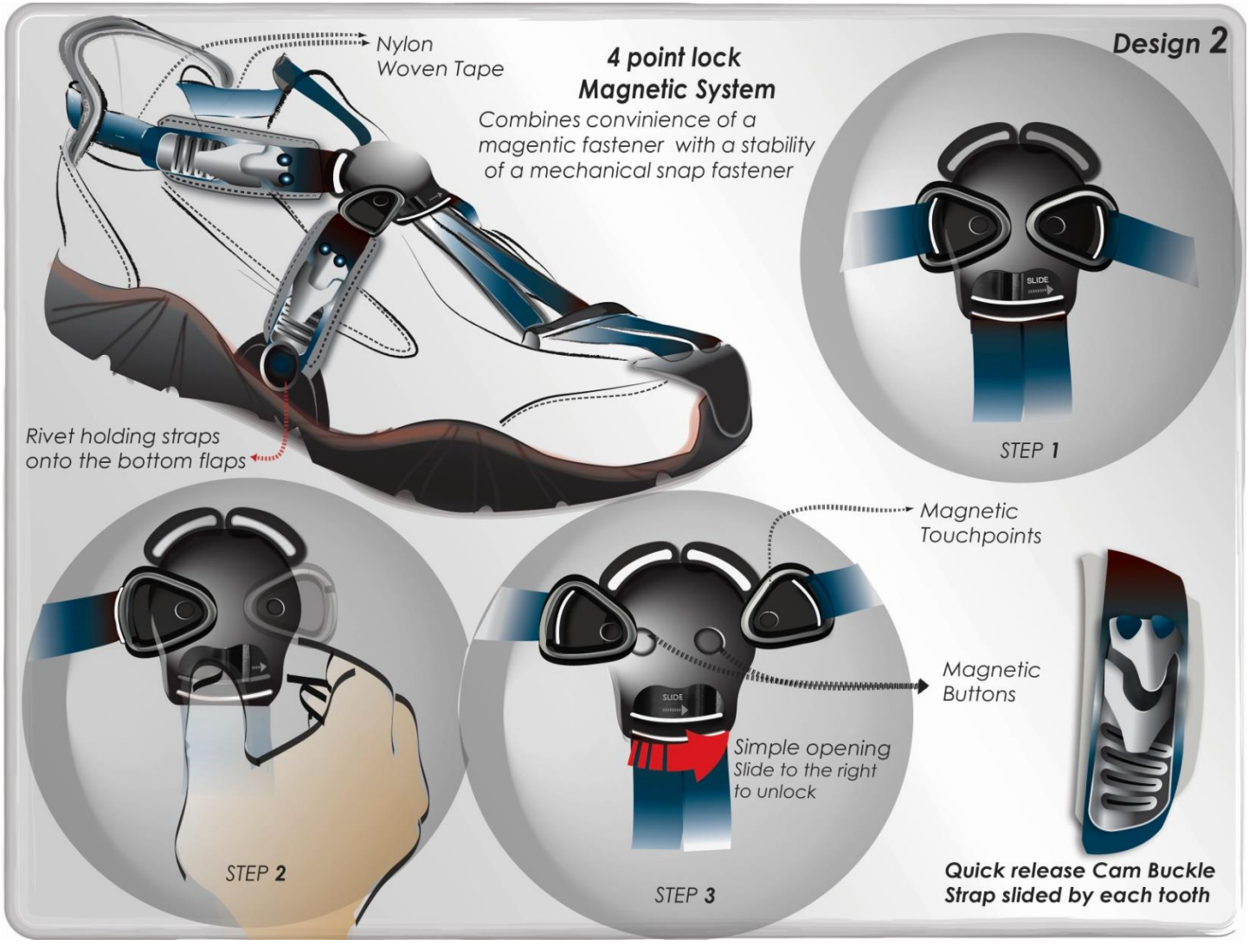
Brainstorming Lines


Closing, joining & securing
mechanical snap system
with magentic force



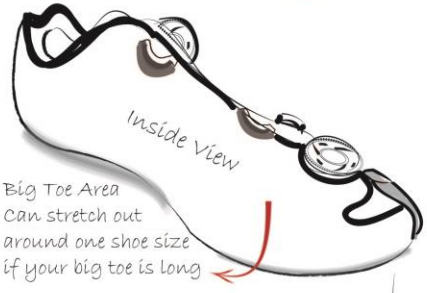

Simple opening
Slide to the right
to unlock

Magnetic
Buttons

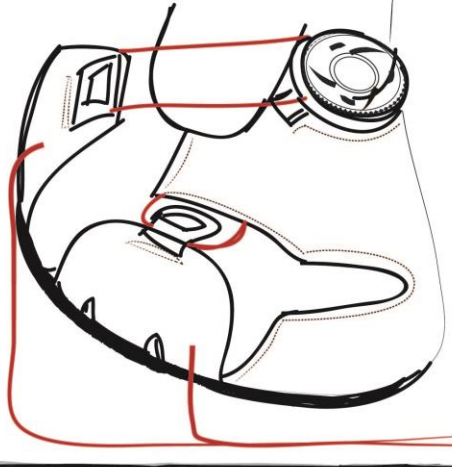

Design 2
Nylon
Woven Tape
4 point lock
Magnetic System
Combines convinience of a
magentic fastener with a stability
of a mechanical snap fastener
Rivet holding straps
onto the bottom flaps
SLIDE
STEP 1
STEP 2
Magnetic
Touchpoints
Magnetic
Buttons
Simple opening
Slide to the right
to unlock
STEP 3
Quick release Cam Buckle
Strap slided by each tooth

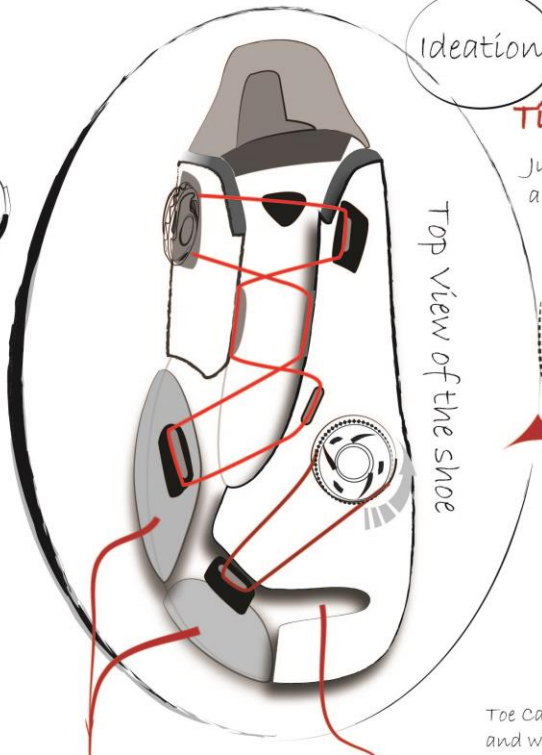
# Design 3

Ideation



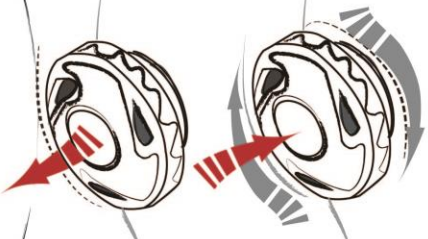

Big Toe Area
Can stretch out
around one shoe size
if your big toe is long






## Tightening Dial System

Just put on the correct shoe size
and tighten the dials until comfortable



Toe Cable tightens shoe
and width together

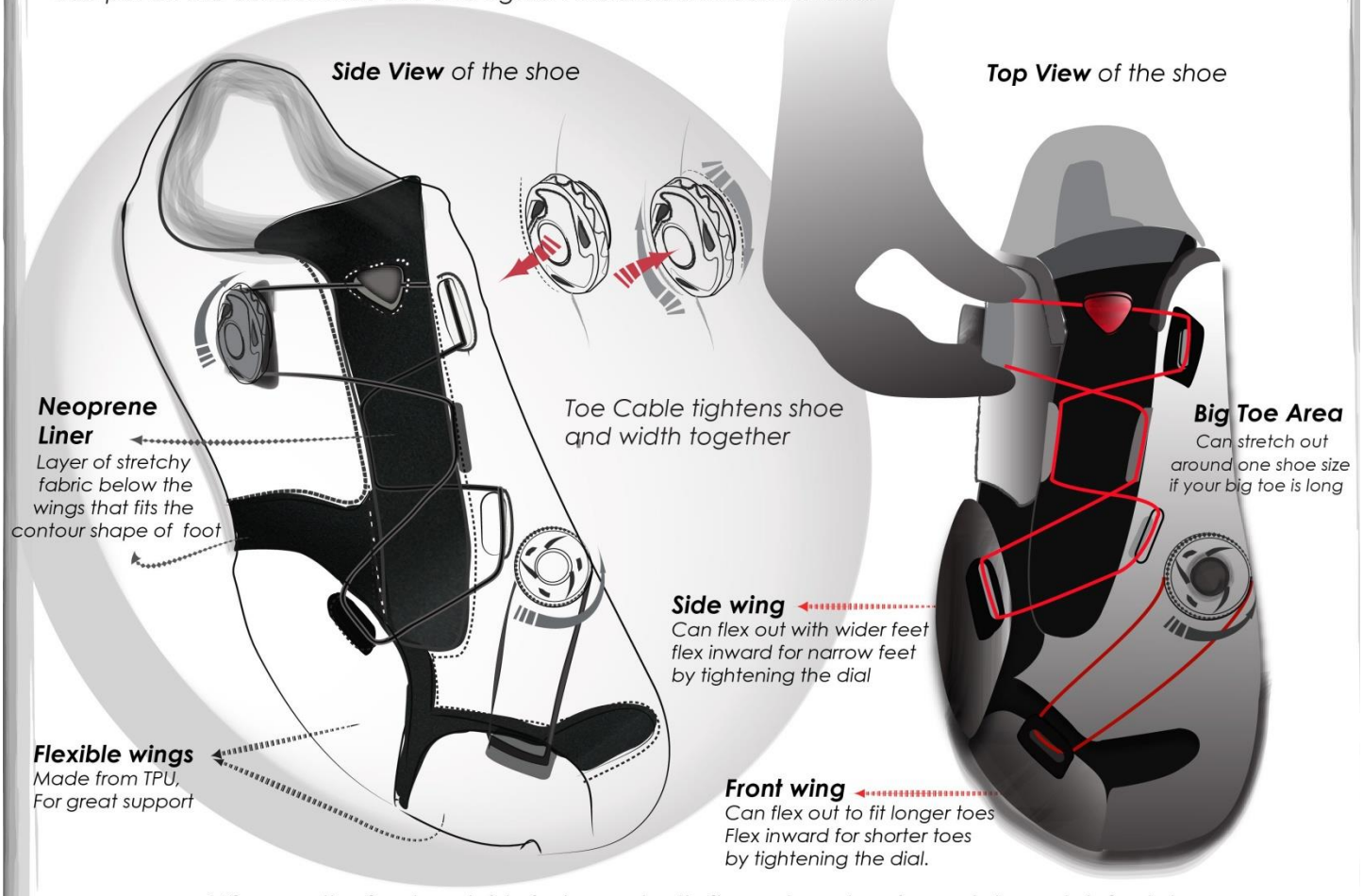
**Side & Front Wings**
Can flex out with wider feet
flex inward for narrow feet
by tightening the dial

**Neoprene Liner**
Layer of stretchy
fabric below the
wings that fits the
contour shape of foot

## Tightening Dial System

**Design 3**

*Just put on the correct shoe size and tighten the dials until comfortable*

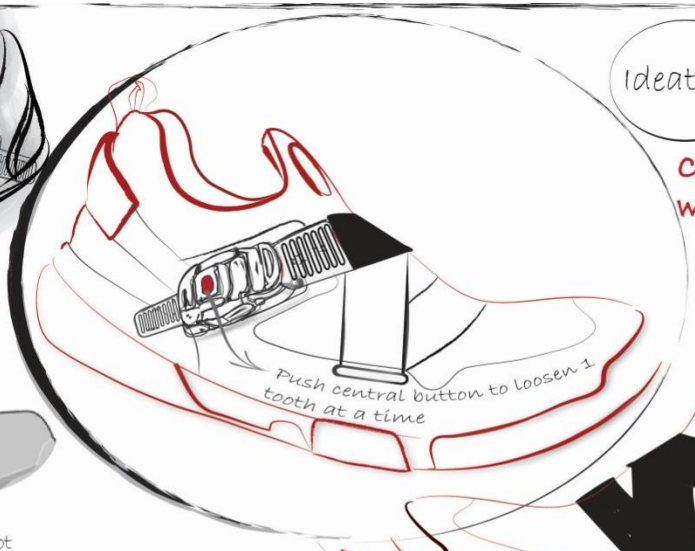



*Wings on the front and side independently flex outwards or inwards to match foot shape*

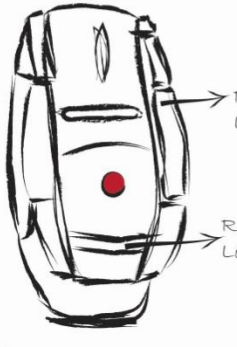
Ideation

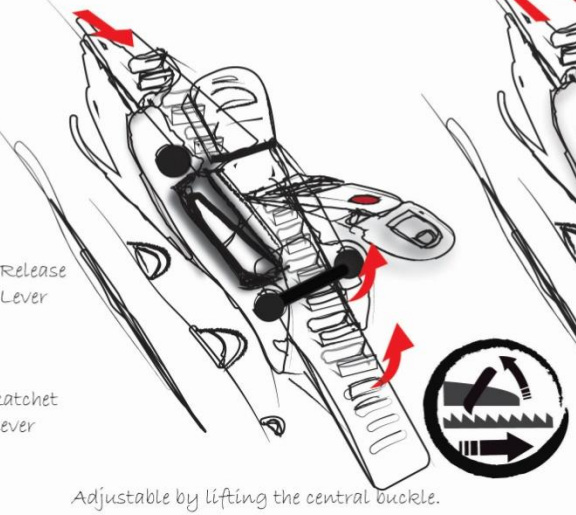
# Design 4

## Calibrating Buckle with Micrometer Gauge

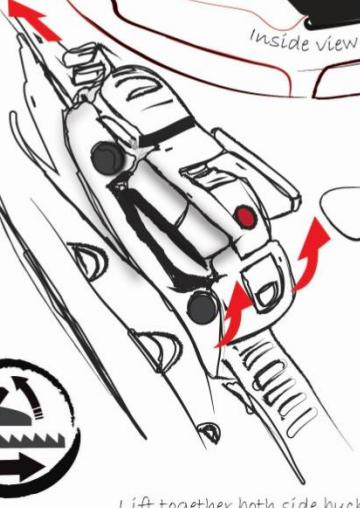



Accommodates extension/flexion of the foot

Adjustable by lifting the central buckle.

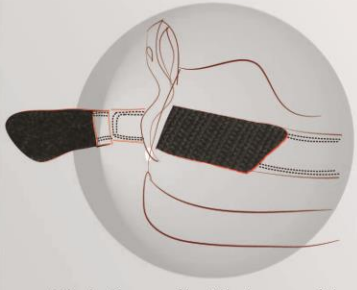


Lift together both side buckles to completely open

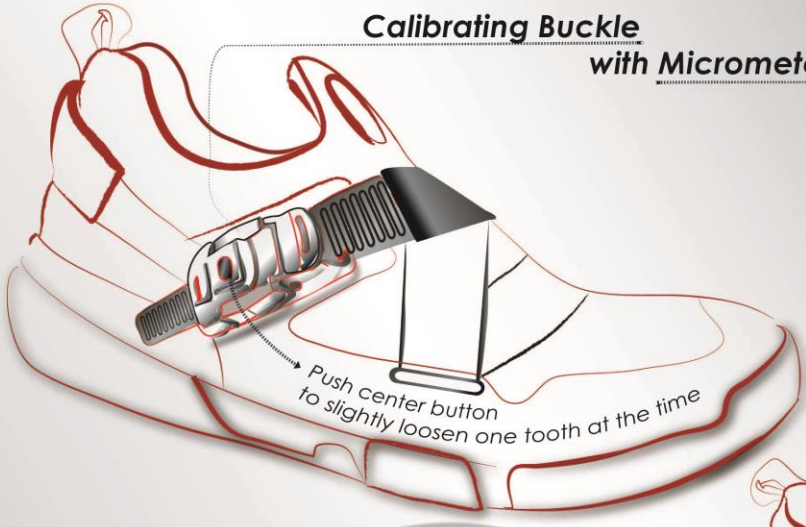
High Security Velcro with integrated locking teeth

Design 4.

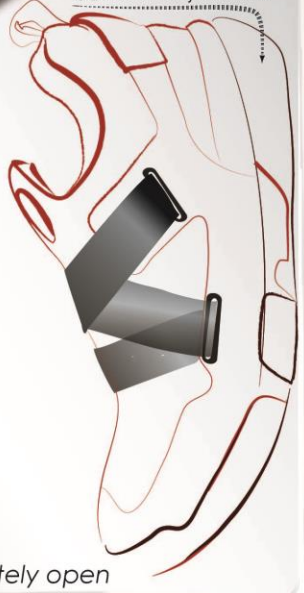
## Calibrating Buckle with Micrometer Gauge

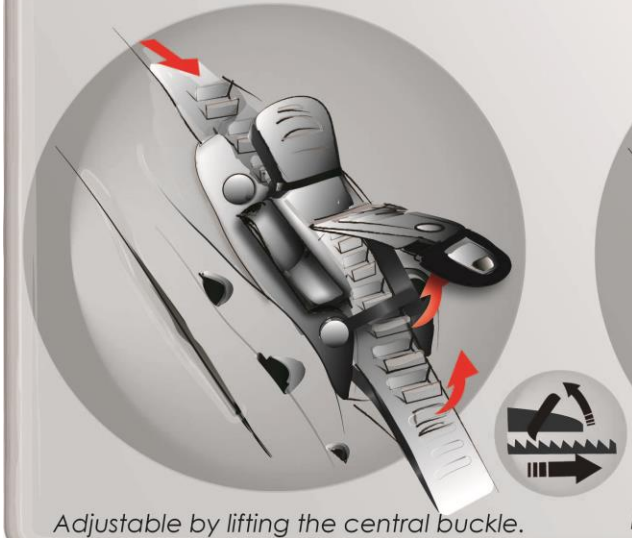


High Security Velcro with integrated locking teeth

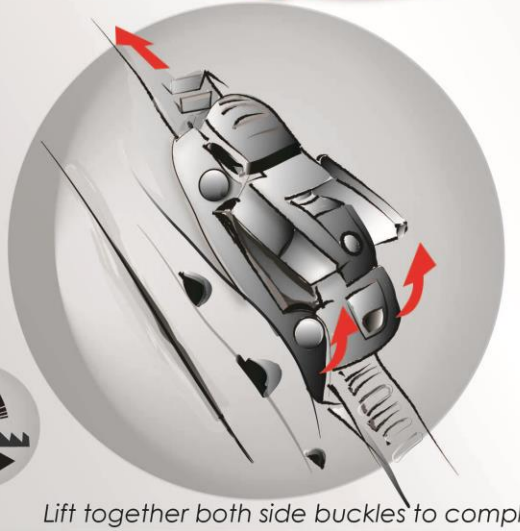



**Inside view** of the shoe interlocking straps for better fit adjustment





Adjustable by lifting the central buckle.



Lift together both side buckles to completely open

# Design 5

Inspiration

Ideation

**DOUBLE CLOSURE SYSTEM**
**CORD LACE INNER CLOSURE**
**ZIPPERED OUTER CLOSURE**

**INTEGRATED GRAVEL GUARD**
extra piece used with fishing boot to keep debris and gravel out

ALTERNATIVES

MID CALF HEIGHT

VELCRO BACKED ZIPPER FLAP

INNER SHOE

STURDY ZIPPERED ENTRY TO THE INNER SHOE

EXTERNAL ANKLE CLOSURE

Extra large loop use fingers/boot hook tool to pull the boots on

GAITERS HOOK

Back tab for easy pull and sliping in your foot

Simple Cinch-Lock closure mechanism

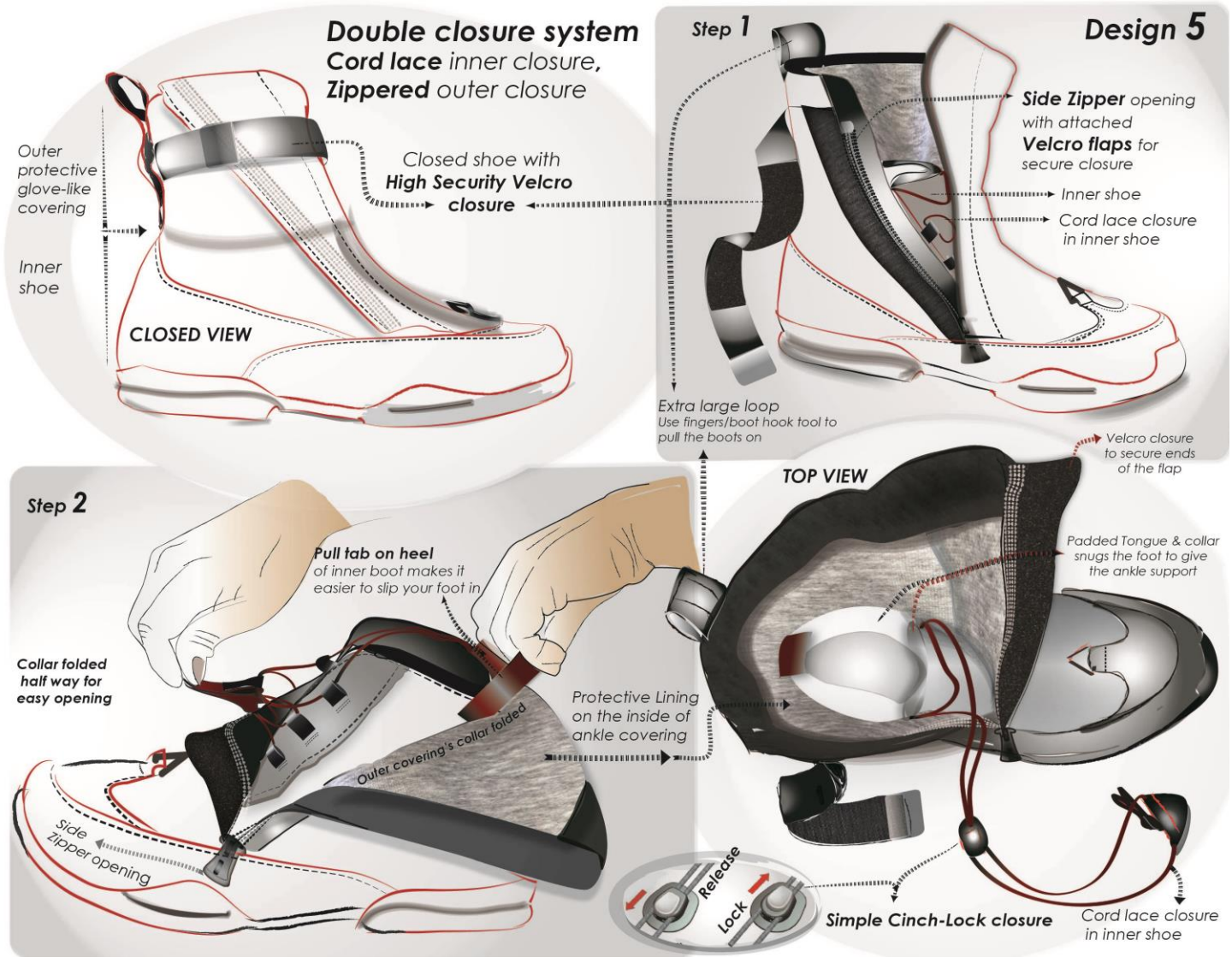
RELEASE

LOCK

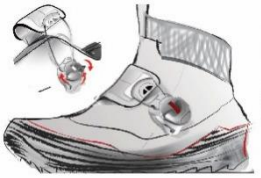
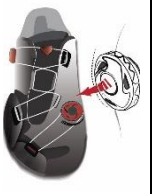
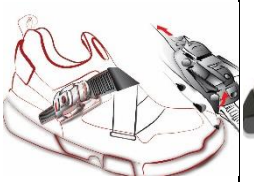
LOOPS FOR CORD PASSAGE

FOLDED COLLAR

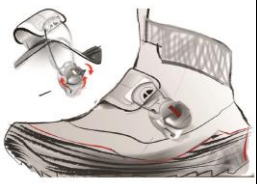
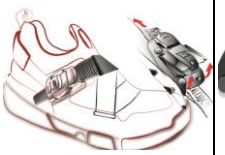
Inspiration
Fishing Bag


Double closure system
Cord lace inner closure,
Zippered outer closure
Outer protective glove-like covering
Inner shoe
CLOSED VIEW
Closed shoe with High Security Velcro closure
Step 1
Design 5
Side Zipper opening with attached Velcro flaps for secure closure
Inner shoe
Cord lace closure in inner shoe
Extra large loop
Use fingers/boot hook tool to pull the boots on
Step 2
Pull tab on heel of inner boot makes it easier to slip your foot in
Collar folded half way for easy opening
Outer covering's collar folded
Side zipper opening
Protective Lining on the inside of ankle covering
TOP VIEW
Velcro closure to secure ends of the flap
Padded Tongue & collar snugs the foot to give the ankle support
Release
Lock
Simple Cinch-Lock closure
Cord lace closure in inner shoe

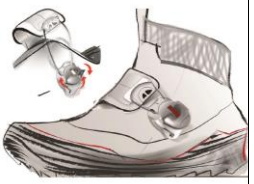
**Part I: Protection**

| Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|
|  |  |  |  |  |
| **Buckle with Dial System** | **4 point Lock Magnetic System** | **Tightening Dial** | **Calibrating Buckle** | **Double Closure Cord Lace Inner Zippered Outer** |
| Looks most **securely fastened** (in terms of proper alignment/adjustment of closure) | | | | |
| | | | | |
| Offers a **clean look** and do away with messy knots and bows | | | | |
| | | | | |
| Appears to stay put during fishing activity (**Powerful lock**) | | | | |
| | | | | |
| Sheds water, Mud, and Ice, shaving precious weight (**Lightweight**) | | | | |
| | | | | |
| Looks most **durable** | | | | |
| | | | | |
| Could fight **water retention** | | | | |
| | | | | |
| Ensures continuously high locking force with **sturdy closure** (**closing** mechanism) | | | | |
| | | | | |
| Could provide reliable closure **every time you put it on and off** | | | | |
| | | | | |
| Provides a **fail-safe mechanism** | | | | |
| | | | | |
| Reduces the **transport of aquatic invasives** | | | | |
| | | | | |
| May offer **water protection** | | | | |
| | | | | |

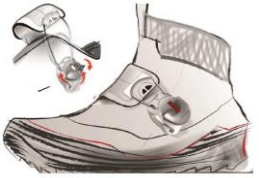
**Part II: Mobility**

| Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|
|  |  |  |  |  |
| **Buckle with Dial System** | **4 point Lock Magnetic System** | **Tightening Dial** | **Calibrating Buckle** | **Double Closure Cord Lace Inner Zippered Outer** |
| Best optimized for speedy swapping between events (**Fast on and off transition**) | | | | |
| | | | | |
| **Convenient** and easy adjustments (On-the-Fly) | | | | |
| | | | | |
| Excellent **freedom of movement** without rubbing on the skin surface | | | | |
| | | | | |
| Offers fastening with **less user-engagement** | | | | |
| | | | | |
| Offers great **flexibility** in bending over and fastening shoes (easy maneuver) | | | | |
| | | | | |
| Balances **cushioning** and **motion control** (everything from limiting excessive foot motion to allowing feet to move as nature intended) | | | | |
| | | | | |
| Enables **easy opening** even **while wearing gloves** | | | | |
| | | | | |

**Part III: Fitting**

| Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|
|  |  |  |  |  |
| **Buckle with Dial System** | **4 point Lock Magnetic System** | **Tightening Dial** | **Calibrating Buckle** | **Double Closure Cord Lace Inner Zippered Outer** |
| Offers seemingly infinite degrees of **fine tuning** in fit adjustments (**Micro-adjustability**) | | | | |
| | | | | |
| Adequate stability, in terms of **resisting foot compression and twisting (Snug fit)** | | | | |
| | | | | |
| Offers **Custom fit comfort (Adapts** best **to the shape** of the foot) | | | | |
| | | | | |
| Offers even closure with **no pressure points** | | | | |
| | | | | |

**Part IV: General**

| Design 1 | Design 2 | Design 3 | Design 4 | Design 5 |
|---|---|---|---|---|
|  |  |  |  |  |
| **Buckle with Dial System** | **4 point Lock Magnetic System** | **Tightening Dial** | **Calibrating Buckle** | **Double Closure Cord Lace Inner Zippered Outer** |
| Most **innovative** solution | | | | |
| | | | | |

| | | | | |
|---|---|---|---|---|
| Attractive for very **diverse area of applications** (backpacks, lifestyle products, other sports attire) | | | | |
| | | | | |
| Best from **commercial stand-point** | | | | |
| | | | | |
| **Easy maintenance** (replacement and cleaning) | | | | |
| | | | | |

**Additional Comments:**

*Thank you for taking the time to complete this questionnaire!*

If you have any questions regarding the questionnaire, please contact me or my advisor at:

Ruchireeka Rath: rurath@mix.wvu.edu
Professor Craig Nelson: Craig.Nelson@mail.wvu.edu

# APPENDIX C: FINAL EVALUATION QUESTIONNAIRE

# DESIGN AND EVALUATION OF FUNCTIONAL GEAR FOR PROTECTION, FIT AND MOBILITY-

## Fishing footwear

**Ruchireeka Rath**
Graduate Student
Design & Merchandising
Davis College of Agriculture, Natural Resources and Design
West Virginia University
Morgantown, WV 26506

**Design and Evaluation of Functional Gear for Protection, Fit and Mobility- Fishing Footwear**

Conventional fasteners like laces, cords or elastic can cause difficulties and even danger to the wearer if they come undone during a fishing activity. Among the dangers are slippages of the associated shoe relative to the foot of the wearer and associated instability as well as the tripping danger in the event, if the untied lace is stepped on or becomes tangled. Accordingly, a need exists for an easy-to-use fastening system which securely fastens the shoe while adding minimal bulk, and which is easy to fasten and unfasten by the user. Thus there is a desire and an unmet need to provide shoe closure devices that accomplish the closure mechanism of conventional tie laces in an effective and efficient manner.

This **research aims to create a novel, utilitarian fastening concept in fishing footwear**. Based on investigative study and market research, the solution will be developed through iterative design process to meet the needs of the fishing folks (improving fitting, protection and mobility).

**Instructions**: Detailed illustrations for the selected design concept used in this study is provided. This is followed by a series of questions. For each question, please answer one among the three choices by selecting/ticking the corresponding box – Yes, Maybe or No. Please do NOT select anything if you are unsure of the answer or encounter difficulty understanding the question. Do NOT select/tick more than one boxes. For additional comments, please use the "Additional Comments" section towards the end of this questionnaire.

**Example:** Assume that you feel the water retention capability of the proposed design to be ineffective, tick "No" in the box indicated below.

| Performance Assessment Criterion | Yes | Maybe | No |
|---|---|---|---|
| Fight water retention | | | ✓ |


Outside view
of the Fishing Boot
Buckle with Dial System
On-The-Fly Adjustments
Soft,
padded
instep strap
Outside flap
holding ratchet
wire
Inside flap
holding
micrometer
ratchet strap
Goretex fabric upper
for water resistance
Insulated waterproof lining
Molded Toe cap
Gusseted collar topline
Large back loop for
easy foot insertion
Inside view
of the Fishing Boot

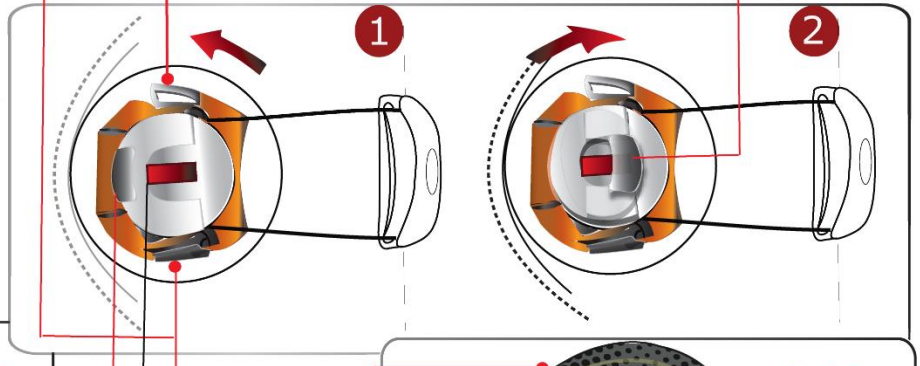
Outer Strap View

## Technical Overview : Buckle with Dial System Fastener

Push 2 side levers on either side of the dial to release the wires

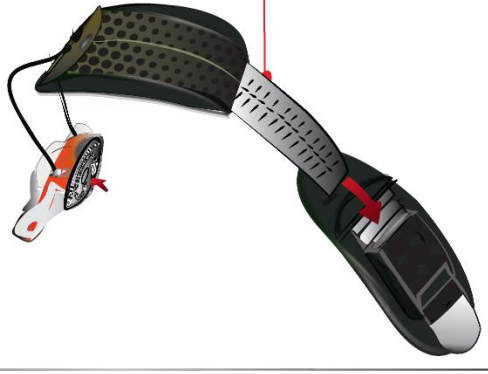
- Push RED BUTTON to lift the BUCKLE FLAP UP for length adjustment of the loop

Rotate the Dial clockwise to tighten,
Once desired tightness is reached, the tab flips down




Micrometer adjustment allows precise sound pressure distribution

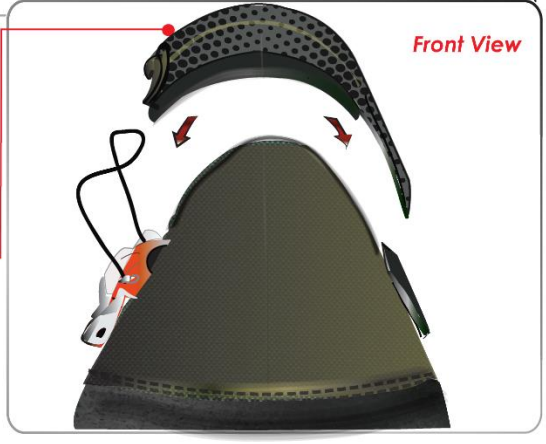
Inner Strap View



Release lever
Red Button
Buckle flap
acts as a
Ratchet Lever

Great Ratchet tightening to adjust both inner & outer of the shoe, across the instep

Front View



| Decision Matrix | | | |
|---|---|---|---|
| **Performance Assessment Criterion** | **Yes** | **Maybe** | **No** |
| **Secure & Sturdy mechanism** | | | |
| **Fight water retention** | | | |
| **No transport of aquatic invasives** | | | |
| **Fast on/off transition** | | | |
| **Convenient & Easy opening** | | | |
| **Less user-engagement** | | | |
| **Micro-adjustability** | | | |
| **No pressure points** | | | |
| **Diverse area of applications** | | | |
| **Commercial stand-point** | | | |

**Additional Comments:**

*Thank you for taking the time to complete this questionnaire!*

If you have any questions regarding the questionnaire, please contact me or my advisor at:

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Professor Craig Nelson: Craig.Nelson@mail.wvu.edu