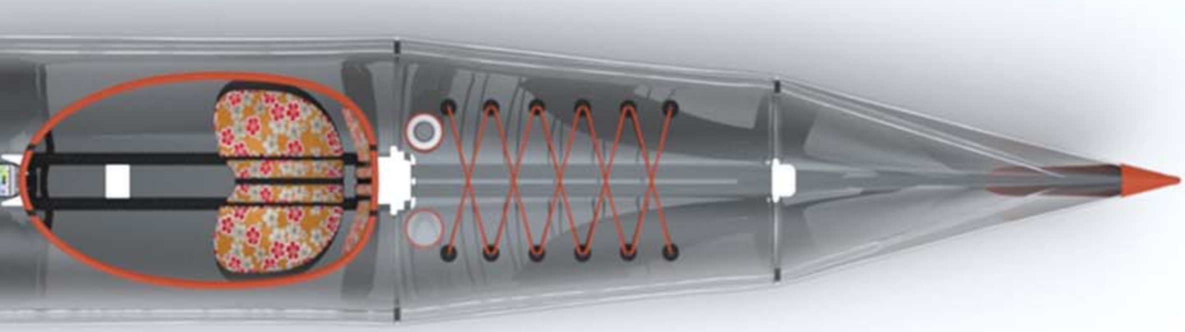


Integrating the Kayak Transforming a Lifestyle

A design-led exploration of transforming kayaks as lifestyle enablers.

An exegesis presented in partial fulfilment for the degree of Masters of Design at Massey University, Wellington, New Zealand.

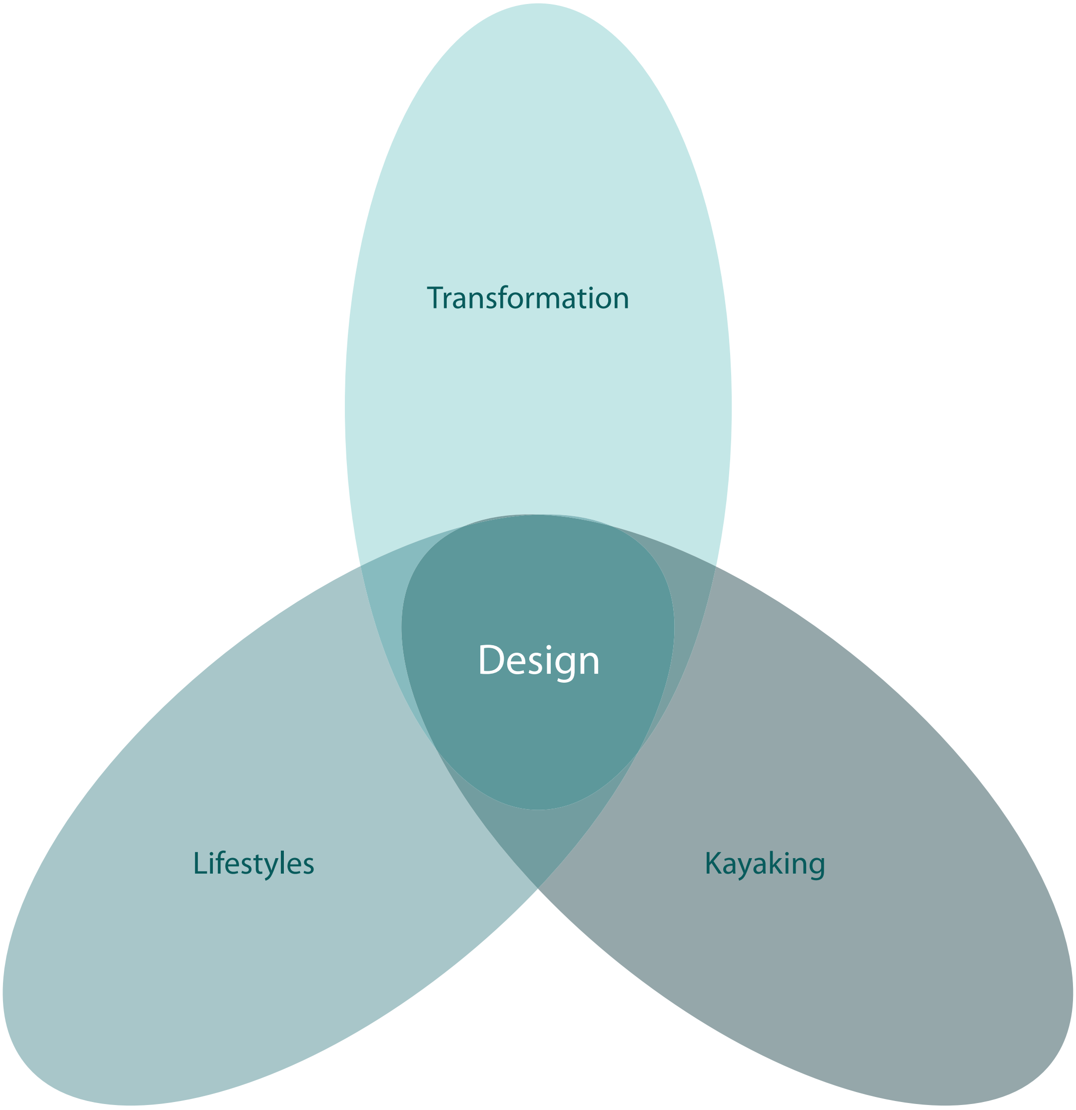
By Jason Mitchell, 2016.

Jason Mitchell

M.O.R.P.H. Lab Transformation Framework

Objects

Systems



The three subject areas in this study that combine to inform the design of transforming kayaks

The kayak Experience Survey

Lifestyle Factors

Market Review

Evolution

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Abstract

This study uses design-led research to validate the hypothesis that the design of current transforming kayaks does not meet the needs of the modern user.

Research identified lifestyle factors affecting the kayaking experience and compared them to current transforming kayak models. Opportunities were revealed for new transforming kayak designs that would help to overcome modern lifestyle barriers to kayaking.

Primary lifestyle factors indicated the time available, portability, and the type of accommodation lived in were the most influential factors affecting peoples' ability to engage in kayaking. Secondary factors highlighted specific focused elements where design could be most beneficial.

The transforming kayak, better known by the generic term 'folding kayak', is a small watercraft capable of packing down to a portable state for transportation and storage. Used extensively during World War 2 by the military, transforming kayaks became popular in post-war Europe as leisure craft, significantly outnumbering their non-transforming counterparts. Despite the potential transformation has to overcome barriers to kayaking, the current design of transforming kayaks caters to only a fraction of the market it once did.

This study adopted the University of Texas 'M.O.R.P.H. Lab Transformation Framework' to identify principles and facilitators inherent in product transformation. This framework was imperative in evaluating existing kayaks and successful product systems. The use of heuristics aided in the development of new transforming kayaks. Transformation as a meta-theme in the design of products is positioned within the interrelated fields of modularity, adaptable design, and fields where objects change state, or are reconfigured for a specified purpose.

A heuristic, iterative prototyping process led to experimenting with M.O.R.P.H. facilitators themed around folding and sliding systems and resulted in a series of transforming kayak prototypes validated through proof of concept, with further potential for future development outside of this study.

Key innovations include integrating all kayak components and developing a central point of deployment. This resulted in systems with faster deployment times and resolved issues of complexity and loss of components within transit.

Research builds on the ideas of using transformation in industrial design as a means to allow flexible and adaptable solutions, specifically within the design of transforming kayaks.

Acknowledgements

There are a number of people I would like to thank for their contribution and support during this study.

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1.0 Introduction

This study is inherently about designing systems. The *American Heritage Dictionary of the English Language* (2011) provides a useful description of this project's approach to systems: "A group of interacting, interrelated, or interdependent elements forming a complex whole"(n.p.). The 'complex whole' in this study refers to the transforming kayak: a small, semi-enclosed, human-powered boat. The 'interacting, interrelated elements' are the functional components that transform a portable package into a fully functional kayak.

Historically referred to as folding kayaks, these clever watercraft have the potential, through their transformation, to provide flexibility and freedom for users with diverse requirements. This study explores transforming structures with the aim of challenging the boundaries of existing kayak design. By exploring the potential for new transforming kayak designs, I will look at how these designs might allow more people to participate in the sport. The study is exploratory, with the aim of designing transforming kayaks with potential solutions rather than fully resolving a specific design.

I approach this study as an Industrial Designer with a passion for bringing my ideas to life through the act of making. Being actively involved in the maker movement through the Fablab network has helped shape the way I work as a designer. My work meets at the crossroads of pragmatism and dreams. The pragmatist in me brings professional experience, designing boats for international, commercial and recreational markets, and the dreamer in me looks to pioneer new ideas in the marine industry.

While designing boats I lived in the Marlborough Sounds surrounded by hidden inlets, beaches and islands. As an avid kayaker I would wrestle my kayak onto the roof of my car for an after work paddle. The quiet rhythm of my paddle hitting the water while exploring the coves near my home was my Zen moment. It was my escape, my meditation, medication, and exercise.

A year later and living in a city apartment, my lifestyle was suddenly much busier and more crowded. The Zen moments were fewer and further between. I sold my kayak when life got in the way; the combination of work, family and a small apartment made kayaking a challenge. How could I merge my old life of the after work paddle with my new busy life in the city? I tried an inflatable kayak, and while it afforded significant storage benefits through transformation, it also created other barriers — especially the time it took to set it up. If this was a problem for me, it must also be a problem for others. This was the catalyst and my inspiration for the design challenge ahead.

These ideas come together to pose the main question being explored in this study:

> Can new transforming kayak designs remove barriers to participation?

Ultimately this question is explored through design. Making, testing, reflecting on and refining different transforming kayak systems using transformation to overcome lifestyle barriers.

Two further questions were necessary to inform the design process:

> What are the lifestyle factors that impact and influence transforming kayak ownership and participation for which I am designing?

And; What design opportunities can be taken from examining existing transforming kayaks and other transforming objects?

Transforming kayaks have a rich history, with many innovations born from their use as covert vessels during the Second World War (Rees, 2009). A post-war surge in popularity saw them on the waterways of Europe as ubiquitous weekend silhouettes always visible somewhere on the horizon. Their popularity was infectious, slowly spreading across the Atlantic to American waters (Diaz & Theroux, 2003).

While transforming kayaks no longer command the presence they once did on the water, kayak participation around the world is currently on the rise. Data on participation in sport and recreation released in 2012 by the Australian Bureau Of Statistics revealed participation in kayaking grew 113 per cent.(Australian Bureau of Statistics, 2012). American statistics show a trend over three years to 2011 of a 32% increase in recreational kayaking, and over one year an increase of 27%, with numbers of users increasing from 6,465,000 to 8,678,000 (Hansel, Bryan, 2012).

For this study, The Kayak Experience Survey (2014) investigated kayak ownership, usage and experiences. Results showed that only 6% of survey respondents had chosen to purchase a transforming kayak. (This number significantly increased, however, when surveying specific transforming kayak forum member's experiences.)

Theories vary as to why transforming kayaks currently have such a limited market share. Davis (2011), author of *Build You Own Canoe*, alludes to the shift from public to private transport as being an influence. As the motorcar became a viable alternative to train travel, luggage space became less of an issue and so the need for kayak transformability became less important.

Ralph Diaz suggests that the flood of cheap plastic kayaks onto the market in the 1980s was responsible for a significant drop in transforming kayak purchases (Diaz & Theroux, 2003). If market share of transforming kayaks is to be increased then design needs to be revolutionary enough to overcome the barriers to participation and connect with modern living.

Ohr author of the 'Integrative Innovation' blog writes: "Evolutionary innovation only optimizes and exploits existing businesses and prolongs their trajectories. Revolutionary innovation, in turn, explores new-to-the-world opportunities and creates new business potential". (Ralph-Christian, 2012, para. 3)

The design process centres on the user, but is careful not to be user-led. This is a design philosophy, explained by Skibsted and Hanson (2014), of both Apple and Ikea. User research, they claim, should be used as guidance rather than a directive as users often don't know what they want. User-led design can stifle innovation, and being too formulaic will miss out on disruptive technologies and ideas. (Skibsted & Hansen, 2014).

In order to benchmark the user experience, my research included people who paddle solid-state kayaks as well as those using transforming kayaks. The successful design elements of solid-state kayaks needed to be determined, and the possibility of incorporating them into transforming kayak design considered. This study also considered those who have an interest in kayaking but, due to limiting lifestyle factors, do not participate in the sport. Most responses from non-users focused on perceptions of the kayaking experience. These real and imagined experiences helped define potential barriers to kayaking.

Primary user research was conducted with kayak owners through The Kayak Experience Survey (2014). Results were gathered from respondents who were members of forums associated with lifestyle, kayaking, and transforming kayaks. Qualitative analyses of the data provided insights into people's experiences and their less tangible emotional connections to the experience. Quantitative analyses helped to establish the extent of the issues and a hierarchy of their importance.

Problems with transforming kayaks owned by survey participants were reviewed and grouped by category to look at specific design issues. This analysis identified trends showing a hierarchy of design qualities from those that were well resolved to those that would benefit from design intervention.

The context review undertaken as part of this study investigated kayaker's lifestyles as they related to kayaking. Specific lifestyle factors were identified as either enabling or inhibiting the kayaking experience. The factors were then considered when comparing the design of current kayak models, to assess whether the design was effective at meeting the needs of kayakers. This revealed the problems and highlighted opportunities for the design of new transforming kayaks and associated systems, with the potential to allow more people to enjoy kayaking.

Design heuristics were used extensively throughout the process. Heuristics are "cognitive shortcuts that aid designers in exploring design solution spaces, to find diverse and creative concepts" (Yilmaz, n.d. p. 1). Leading design firm IDEO use heuristic cards as a means to inspire empathic research methods (*IDEO Method Cards*, 2003). In a closer context, Per Mollerup identifies a set of common heuristic aides that govern the transition of collapsible objects as explained in his book *Collapsibles* (Mollerup, 2001). In this study I applied the M.O.R.P.H. Lab Transformation Framework which establishes a set of design heuristics called 'Principles and Facilitators'. The heuristics were employed as prompts to help with the creation of ideas and to categorise current transforming kayak models based on the types of systems used to transform them. It was further used as a measure of how each kayak deployed, comparing automation, speed, system complexity and semantics. To gain a wider understanding of transforming systems, a variety of transforming products were also analysed as a means to inspire new transforming systems in kayaks.

The need for a central focus and initiator of deployment, which I refer to in this study as the 'trigger', was also discovered through the use of the M.O.R.P.H. framework. I adopted this into the framework as a significant enabler in my range of design solutions, and it will be referred to in upcoming chapters.

The combined research informed the physical exploration of themed heuristics — a material-led process of test, reflect and refine. In his article titled 'Playing in the Sandbox; The Role Of Experimentation In Designing', Baskinger (2010) promotes experimentation as a means to open the pathways to new and sometimes unexpected innovation (para. 3). Designing a transforming kayak required an approach that was tactile and measurable, and that elicited an immediate response in understanding material behaviour and functionality. Testing through making sped up validation. During design exploration I failed often, but for many of the failed attempts it was the rigour and learning associated with those failures that was a doorway to innovation. Rob Asghar (2014) writes about the Silicon Valley mantra in Forbes magazine: Forget the cute mantras.

> No one should ever set out to fail. The key, really, shouldn't be to embrace failure, but to embrace resilience and the ability to bounce back. The goal shouldn't be to glorify mistakes and errors and catastrophes, but to cultivate the ability to adapt and learn from them. (Asghar, 2014, para. 18)

When exploring new design possibilities for transforming kayaks, the same philosophy and rigour was applied to my material-led experimentation. To push the boundaries of new ideas I wanted to push the boundaries of materials by experimenting outside their traditionally accepted context. Baskinger (2010) talks about how this can benefit the design process: “There are traditional uses for materials and non-traditional uses of materials. Sometimes working with a material outside of its expected application and context can open pathways to finding new opportunities”(Baskinger, 2010, para. 17).

The exegesis is divided into research that informed the design, and research from experimentation and physical exploration that makes up the design. The findings connect the research and design to illustrate that transforming kayak design needs to evolve to remove barriers to kayaking brought about by contemporary lifestyles.

I will discuss how I used transformation as a meta-theme to design a series of kayak prototypes that better enable users. The design section provides a narrative of how the research translates to the design and how the design advances the existing landscape of transforming kayaks to improve participation.

2.0 Transforming Kayak Review

> It is impossible to exaggerate the usefulness of a folding kayak. Even the hackneyed phrase 'flying carpet' is appropriate to this ingeniously conceived craft . . . There is an immense amount to be learned about this deceptively simple boat. I suspect the reason for the folding kayak's complexity is inherent in the boat's design. All other craft have conventional similarities--a little plastic motorboat has many features in common with the QE II, but these have nothing in common with a folding kayak. Consider the shape and construction of the folding kayak, or any skin boat, and you have to reach a conclusion that its nearest equivalent is an animal's body, not a fish but a mammal, a vertebrate. It has an interior skeleton, ribs, joints, a spine; it has a head and a tail, it has a hide, it flexes. To this animal shape the paddler brings a brain, and energy, and guts.
>
> Paul Theroux (Diaz & Theroux, 2003, p. 2)

Theroux's description of transforming kayaks is apt: outwardly they look simple, but hidden beneath the skin is the complexity that provides structure and stability while also allowing the magic of transformation to occur. To understand how to challenge the design of the transforming kayak, it is first necessary to learn from its evolution. This section will briefly discuss the significant historical design achievements and influences and review the designs currently on the market.

2.1 The Evolving Kayak.

Kayaking originated as a tool of survival. The Inuit are thought to have travelled from Siberia, populating Greenland and Alaska (Jones, 2000, para. 1), requiring new modes of travel to be devised. The solution was the Qajaq (small boat) — **Figure 1**. "The frames were usually constructed from driftwood, then later covered by animal hides (usually seals), which were laced and sewn together, acting as the final structural element to an exceptionally strong and durable vessel". (*The Skin-on-Frame Kayak*, n.d., para. 16). While not strictly a transforming kayak, it is clear how the Qajaq has influenced today's transforming kayaks, with the majority still using a textile skin over a rigid frame.

Figure 1. Schertzer, F. 2009. Inuit Kayak. Photograph. CC BY-SA 2.5-2.0

Figure 2.. Caseman. 2004. Klepper_vouwkano. Photograph. CC-BY-SA-3.0

The transforming kayak is a more recent innovation than the solid-state kayak. Most design development occurred during the Second World War when transforming kayaks were used as a reconnaissance and covert surveillance vessels. In his book *Complete Folding Kayaker,* Ralph Diaz (2003) discusses how being lightweight and mobile meant troops could carry the transforming kayaks through difficult terrain when a stealth advance was necessary (pp. 22–23). The first transforming kayak of its kind was the 'Klepper'— **Figure 2**. "Invented around 1900 by a Munich architecture student, in the 1920s it was refined to become a very early example of system design, which did not become widely accepted until the 1950s and 1960s".(*Die Neue Sammlung im Neuen Museum in Nürnberg*, n.d., para. 1). The 'system design' is the process used to transform, and provides the structural integrity of the kayak. The speed of setup and pack-down is the most complex and important aspect of transforming kayak design, and will be discussed through my research.

2.2 Reviewing the Market

Kayaks vary in shape, size and the purpose for which they are used. A kayak is essentially a self-propelled boat, defined by its shape and propulsion method. This study focuses on the most popular sit-in kayak style. Many of the principles of the design have potential application for sit-on kayaks; however, there were no transforming exemplars found throughout the course of this study.

The Kayak Experience Survey (2014), undertaken for this study, provides insight into the types of kayaks owned and their uses (see Appendix 9.3). It was immediately apparent that a high number of respondents owned multiple kayaks for different activities. This begged the question of whether a transforming design could adapt shape, size and speed to user requirements,

thus better meeting users' needs.
Early data from The Kayak Experience Survey (2014) pointed to versatile longer ocean going kayaks being most popular, and these were the focus of design in this study. In terms of popularity sea kayaks topped the list at 50.9%, followed by fishing kayaks at 40.7% as outlined in **Figure 3**. **Figure 4** represents the range of motivations for kayaking identified in the study.

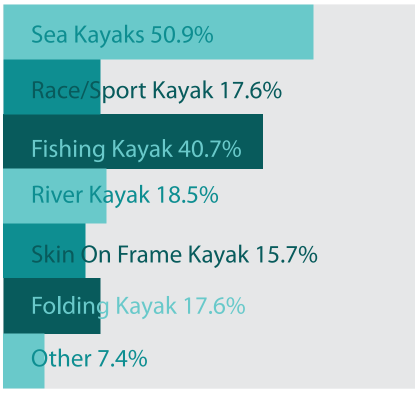


Figure 3. Popularity of the different types of kayaks owned by respondents from The Kayak Experience Survey.

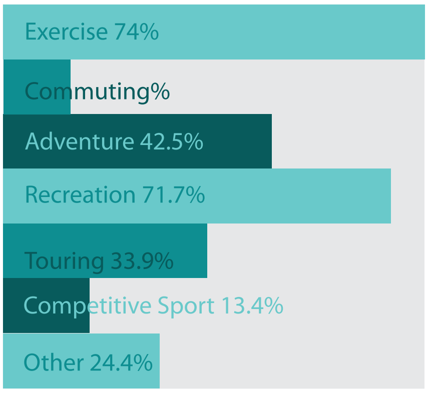


Figure 4. The types of kayaking activities and motivations of respondents from the Kayaking Experience Survey.

2.3 Mapping Kayak Trends

The most popular brands and types of kayaks owned or used by The Kayak Experience Survey (2014) respondents were evaluated. Information from the survey responses was compared to current market kayaks, looking at the range of existing kayak types and transforming systems. The 'Oru' kayak was added to the comparison later as it was not in production until after the survey was complete.

Figure 5 shows the different types of kayaks and an evaluation of the transforming systems used for their deployment. There are effectively three types of transforming kayak systems. The first and most popular is the skin-on-frame kayak. This is the most traditional type and, other than materials and fixings, has not

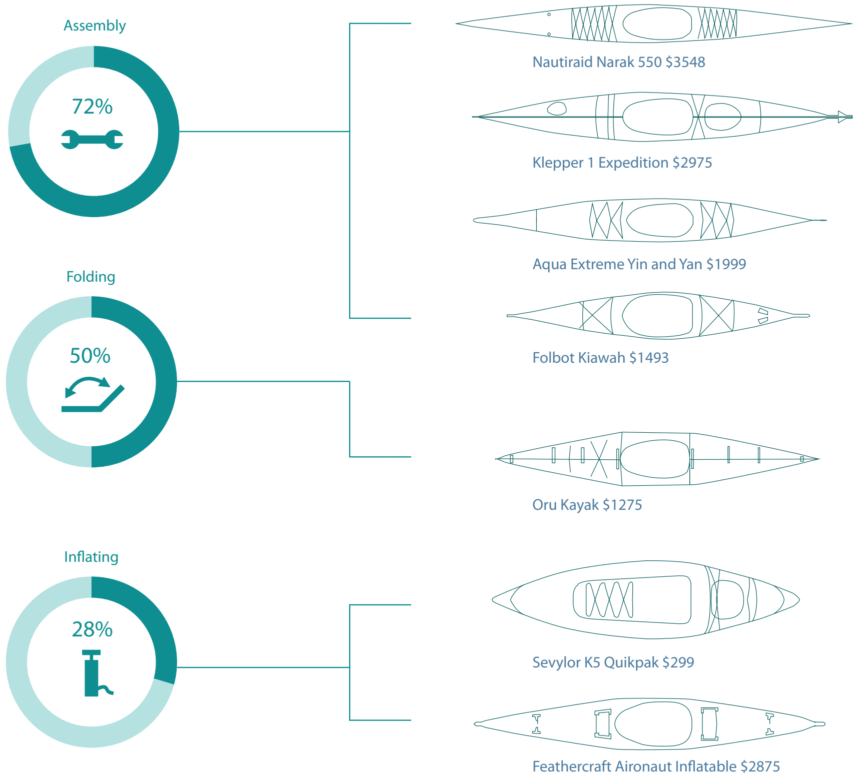


Figure 5. The different types of transforming kayaks and their associated systems. The kayaks are a cross-section of models owned by respondents from the Kayaking Experience Survey.

evolved greatly since its inception - **Figure 6** . This type of kayak is deployed by assembling components and has some folding parts. Next, with a 28% ownership rate is the inflatable kayak. This kayak type uses air pressure to fill PVC voids, creating a fairly rigid structure. Third in popularity is the folding kayak, possibly the only true user of the fold facilitator. This type of kayak uses a semi-rigid, twin-walled plastic skin with pressed fold pattern to transform from a sheet into a kayak. The Oru is the only known example of this type of kayak; however, it is also partially assembled.

As part of the current market analysis, the strengths and weaknesses of transforming kayak design-systems were explored. The survey respondents were asked to rank the most important factors influencing their transforming kayak experience, and

Figure 6. Klaus D. Peter, Wiehl, Germany. 2005. Preparing a Klepper Aerius 2 Folding Kayak. Photograph.

the results were analysed. **Figure 7** with **Figure 8** overlaid shows these results. The values for each kayak were mapped to indicate trends of the different systems, providing a reference for potential opportunities.

There were similarities between how effectively the types of kayaks performed in the different categories. All rated well for portability, with inflatable kayaks having the most compact pack-down size. Most kayaks ranked well for performance, except for the inflatables, which had too much flexibility relative to pressure. Most kayaks were durable, again with the exception of the inflatables, some cheaper inflatable material choices being prone to puncture. The negative factors were consistent —all requiring a long setup time and none able to configure to suit user's needs.

The Kayak Experience Survey (2014) looked at the tasks involved with kayaking, and asked whether the characteristics of a solid state or transforming kayak would best address each task. Figure

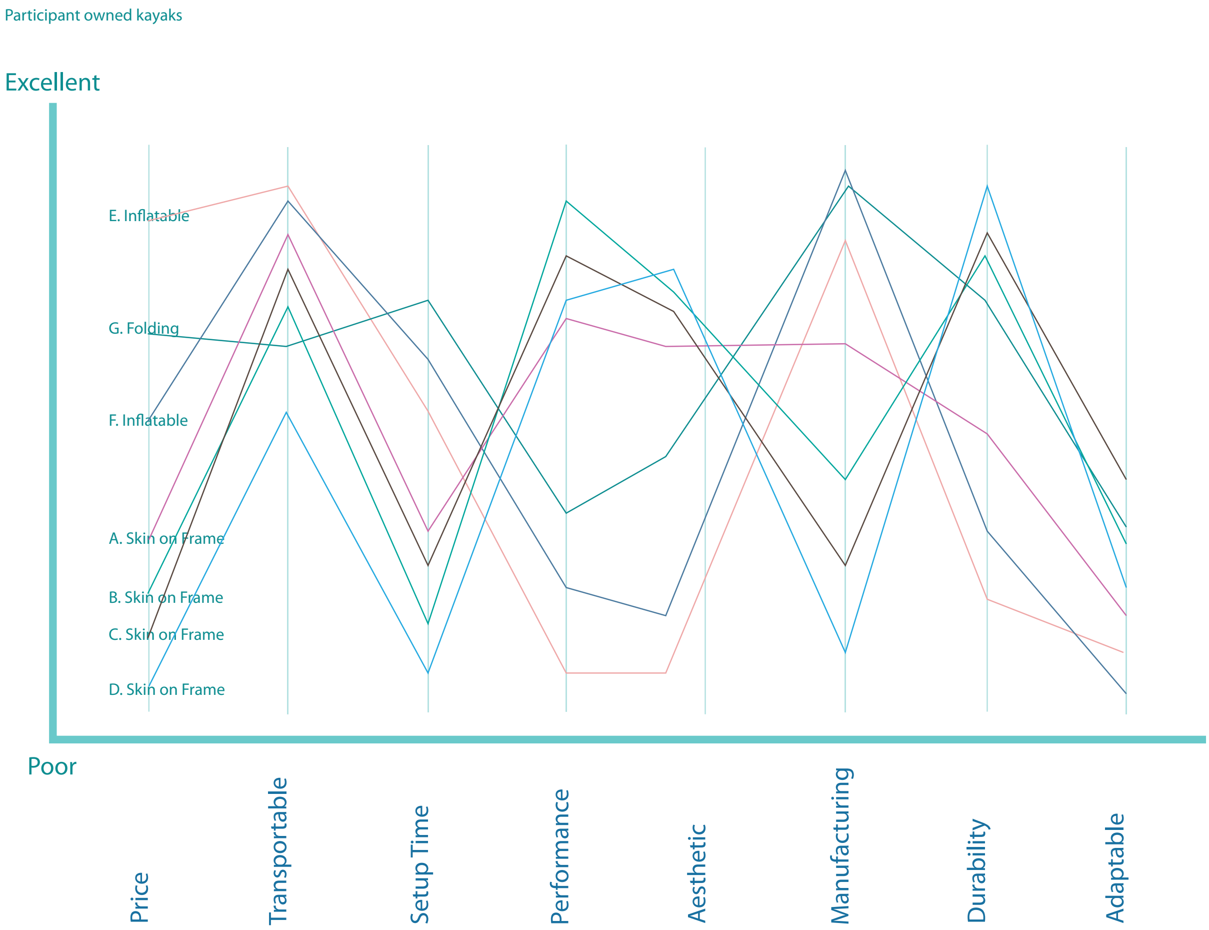


Figure 7&8 Mapping the performance trends of survey participant owned kayaks, graph displays system trends.

9 shows these survey results, with similarities to the current market analysis. The red area shows the disadvantages or perceived disadvantages as design opportunities. The graph shows that the disadvantages outweigh the advantages, and why solid-state kayaks remain the choice of most kayakers.

Transforming kayaks' portability and storage advantages rated well, as expected, when compared to solid-state kayaks. It is interesting to see that the more portable a kayak rated, the lower it ranked in ease and time of set up. This research helped to build a hierarchy of design criteria for new transforming kayak designs.

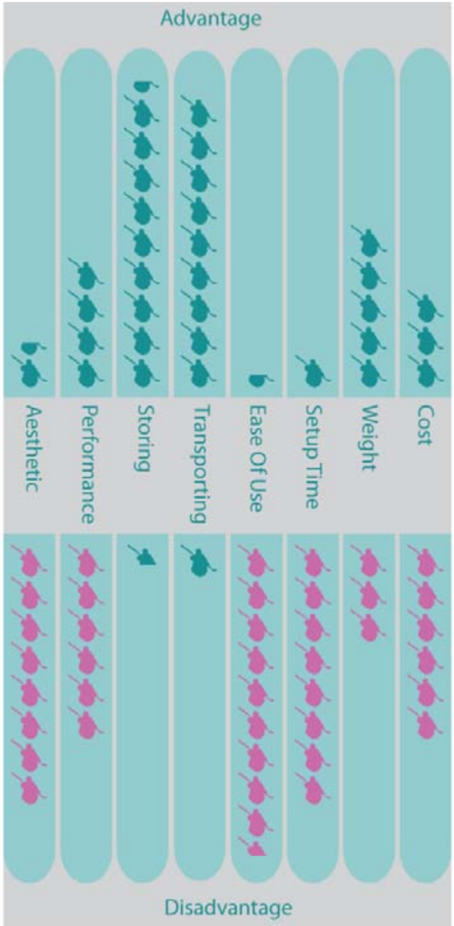


Figure 9. The advantages and disadvantages of transforming kayaks as determined by survey participants.

3.0 Transformation as an Enabler

Objects that physically transform have long held a fascination for me. My childhood 'Transformer' cleverly morphed from a vehicle into a robot ready to fight an imaginary foe. I was less fascinated by the end result than by the magic and reveal of the transformation. As time progressed my fascination with such objects became more pragmatic; the transforming robot was replaced by a compact multi-tool, the Swiss Army Knife. Like the Transformer robot, the knife's multiple functions unfolded to facilitate many an escape from a life threatening situation.

The end result of transformation is often quite obvious and expected, but these objects are the result of a rigorous design process developed around a dynamic system adapting to meet specific needs. The beauty is in the simplicity of the action; the complexity often going unnoticed. The umbrella, for example, stays in a compact form until it rains, then it opens to perform its purpose, and closes again storing away until needed. The umbrella's system uses facilitators described in the M.O.R.P.H. Transformation Framework as 'unfurling' and 'unfolding'. The combination of these facilitators, driven by both mechanical and material solutions, is in itself complex and genius and something I strive to emulate in this study.

3.1 Enabling the Kayaker

As lifestyle supporters, the transforming kayak holds promise for a growing number of users. Think of aquatic commuters happily paddling the city waterways instead of sitting in traffic jams or stuffy subways; or cramped urban apartment dwellers able to enjoy the ocean playground despite having no space to store four meters of kayak; or after-work paddlers not concerned about leaving precious kayaks on car roofs all day while they wait for 5pm paddle time. Adventure is a big motivation for kayakers, and transforming kayaks offer great advantages in their flexibility to explore. Renowned travel writer and novelist Paul Theroux writes:

> I began travelling with a folding kayak and my life changed. You head for the offshore Island, and when you get there you see another, more distant island invisible from the mainland shore; and so you are led onward, self contained and self reliant, island hopping and utterly uplifted. It is almost impossible to exaggerate the usefulness of a folding kayak. (Diaz & Theroux, 2003, p. 6)

To better understand the people for whom I am designing, I used The Kayak Experience Survey (2014) data to help develop a set of personas underlining user needs, motivations and barriers related to impacting lifestyle factors discussed in the next chapter. The personas were designed around a set of scenarios to help build an empathetic approach to design solutions. I used a persona building tool called 'Xtensio' as an aide. ('Xtensio | A Toolbox for Your Startup,' n.d.). Details of the persona can be viewed in Appendix 9.4. Further direction and methodology on personas was learnt from experienced design and strategy firm 'Cooper'.

> Personas are a set of fictional, representative user archetypes based on the behaviours, attitudes, and goals of the people we interview in our research phase. Personas have names, personalities, pictures, personal backgrounds, families, and, most importantly, goals; they are not "average" users but specific characters. A persona is a stand-in for a unique group of people who share common goals; at the same time, persona characteristics encompass those of people in widely different demographic groups who may have similar goals. (Brechin, 2008, para. 6)

3.2 Enabling Lifestyle

The user research identified the three most significant lifestyle factors influencing kayaking. These will be referred to as primary factors throughout this document. These primary factors often share attributes in the way they affect the kayaking experience. Secondary factors were also identified as sub-groups of the primary factors.

The first primary factor established the biggest barrier to kayaking was 'time' — more specifically a lack of it. The Kayaking Experience Survey (2014) questioned respondents on the setup and pack-down time of their kayaks, and results showed the process takes a minimum of 15 minutes for those using inflatable systems and an average of 35 minutes to two hours for other systems, as shown in **Figure 10**.

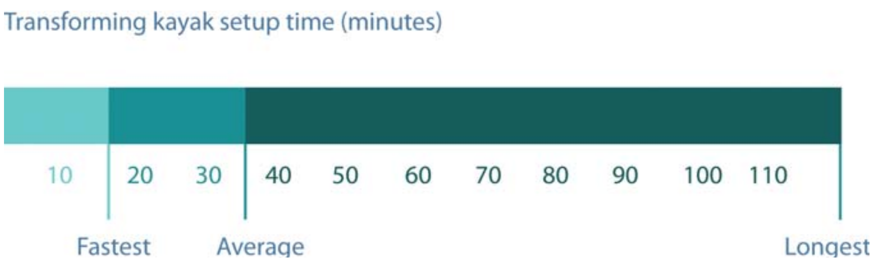


Figure 10. Setup time for transforming kayaks as determined by Kayak Experience Survey respondents.

So in a scenario where two hours are available to paddle, a minimum of 27.5% of that time is spent just setting up a transforming kayak. This doesn't encourage the use of transforming kayaks. As one interview respondent states "I have to say there is no substitute for seat time." (Anonymous, The Kayak Experience Survey, 2014). Another writes "I need a longer time to paddle after work. It's dark by the time I pack down for most of the year and easy to lose parts." (Anonymous, Kayaking Experience Survey 2014).

The second primary factor identified was 'dwelling', or, more specifically, where the user lives. This factor relates mostly to storage, but also to convenience and access. This was rated as a significant advantage for transforming kayaks. The Kayak Experience Survey (2014) data showed that 66.1% of respondents lived in a stand-alone house, 6.3% in townhouses — with likely less storage space, and 29% lived in apartments or other accommodation, e.g. dorms, with little to no available storage space. **Figure 11** shows the comparison. For those in smaller dwellings with less storage space, a transforming kayak would help remove the barriers to kayaking. Some respondents commented on the difficulty of storing kayaks at work. These 4% of commuting workers could be a potential market for the transforming kayak. As one survey participant remarks "I commute, but storing [my kayak] at work is difficult, it doesn't exactly fit under my desk"(Anonymous, Kayak Experience Survey. 2014).

Figure 11. The types of dwellings survey respondents live in. The diagram relates to the kayak storage capacity as it impacts on the kayaking experience.

The third primary factor identified was 'portability', or the ability to transport the kayak using a variety of transport systems. Of the survey respondents 86.6% believed portability would be an advantage if they were to own a transforming kayak. While this result was expected prior to the survey and not really new information, the secondary factors that help or hinder portability directly relate to the design and system of transforming kayaks. Portability is affected by many interrelated design and lifestyle factors: the type of transportation used, the weight and size of the packed kayak, and the speed of setup and pack-down.

Sitting outside of the lifestyle factors are the performance and manufacturing primary factors which are more focused on kayak performance — what it is made from and how it is made.

3.3 Investigating Transformation

This study is positioned within a relatively new field of research in terms of formally categorizing models and frameworks as an aide in the design of transforming objects. Authors of the M.O.R.P.H. Framework Singh et al suggest “Such products have been previously designed employing ad hoc creativity rather than pursuing any formal design methodology.”(Singh et al., 2007, p. 1).

Transformation design sits within fields such as reconfigurable and modular design; both deal with multiple components that adjust to meet particular functions, e.g. modular furniture. Another field associated with transformation is collapsible design championed by Per Mollerup in his book *Collapsible – The Genius of Space Saving Design.* Mollerup describes collapsible design as “smart man-made objects with the capacity to adjust in size to meet a practical need” with “two opposite states, one folded and passive, one unfolded and active” (Mollerup, 2001).

3.4 The M.O.R.P.H. Lab Transformation Framework

The most useful framework for the course of this study was the M.O.R.P.H. Lab Transformation Framework, a theoretical framework centred on the ‘principles and facilitators’ of transformation. Full details of this framework are contained in Appendix 9.2. This framework helped to categorize the complex systems and underpinned the design process. The combination of taxonomy and heuristic experimental methodology allowed structured divergent thinking and abstract ideas to be rationalised. This framework is an evolving study with its roots at The University of Texas M.O.R.P.H. Lab. It is centred around "analogical reasoning and the use of design principles and facilitators, i.e. meta-analogies" (Singh, Walther, Wood, & Jensen, 2009, p. 2). Transformational principles list the three general forms of transformation. "Transformational facilitators describe the various supporting features that aid transformation processes"(J. Weaver, Wood, Crawford, & Jensen, 2010, p. 4) **Figure 12 & 13** (umbrella).

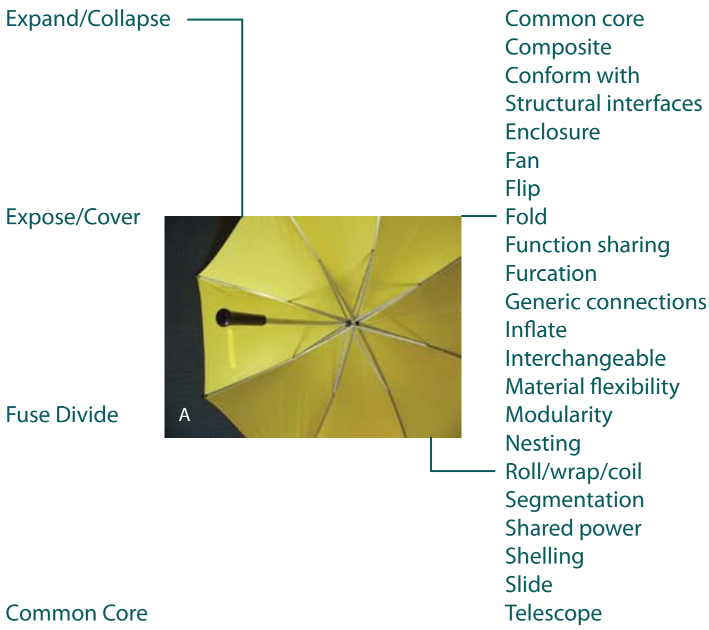


Figure 12 Principles and Facilitators as identified in the M.O.R.P.H. Lab Transformation Framework.

Figure 13. Müller, Frank C. 2007. Gestänge eines aufgeklappten gelben Regenschirms. Photograph. CC BY-SA 2.5.

The M.O.R.P.H. framework lists a number of principles common to transforming objects as a useful guide to be considered in the exploratory stages when experimenting with materials and systems. "A principle is defined as a generalized directive to bring about a certain type of mechanical transformation"(J. M. Weaver, Wood, & Jensen, 2008). "A transformation facilitator is defined as a design construct that helps or aids in creating mechanical transformation. It describes the underlying characteristics or processes that facilitate transformation, but it is not capable of creating transformation outside of an over arching principle." (J. Weaver et al., 2010, p. 5).

3.5 Implementing the M.O.R.P.H. Lab Transformation Framework

The M.O.R.P.H. Lab Framework was used in two stages of this study. Firstly in the research phase to further analyse transforming kayaks and products, and secondly in categorizing and initiating designs.

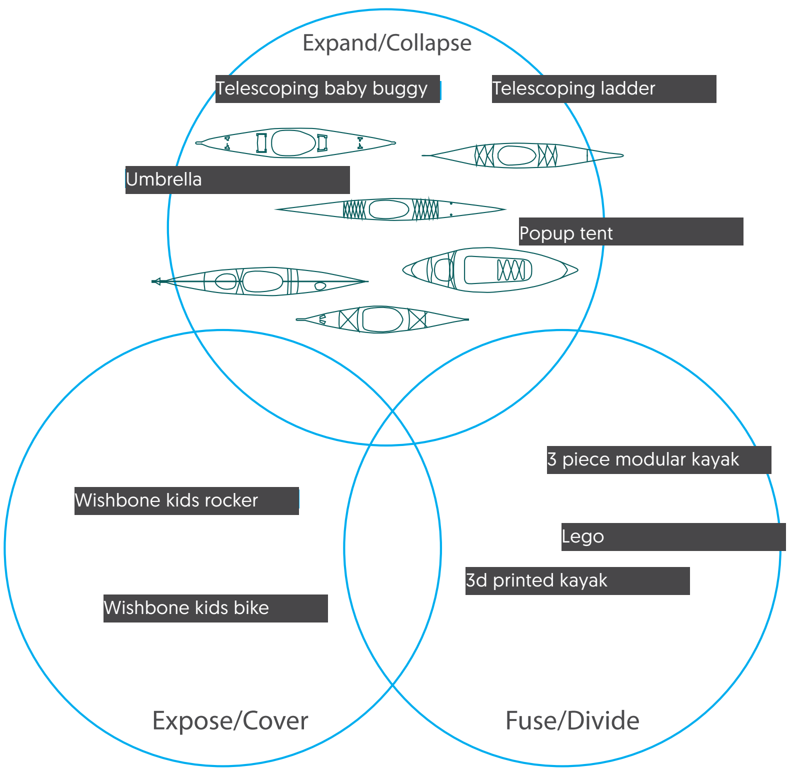


Figure 14. Comparison of transforming kayaks and products using the Morph Transformation framework to categorise the different principles and facilitators of each.

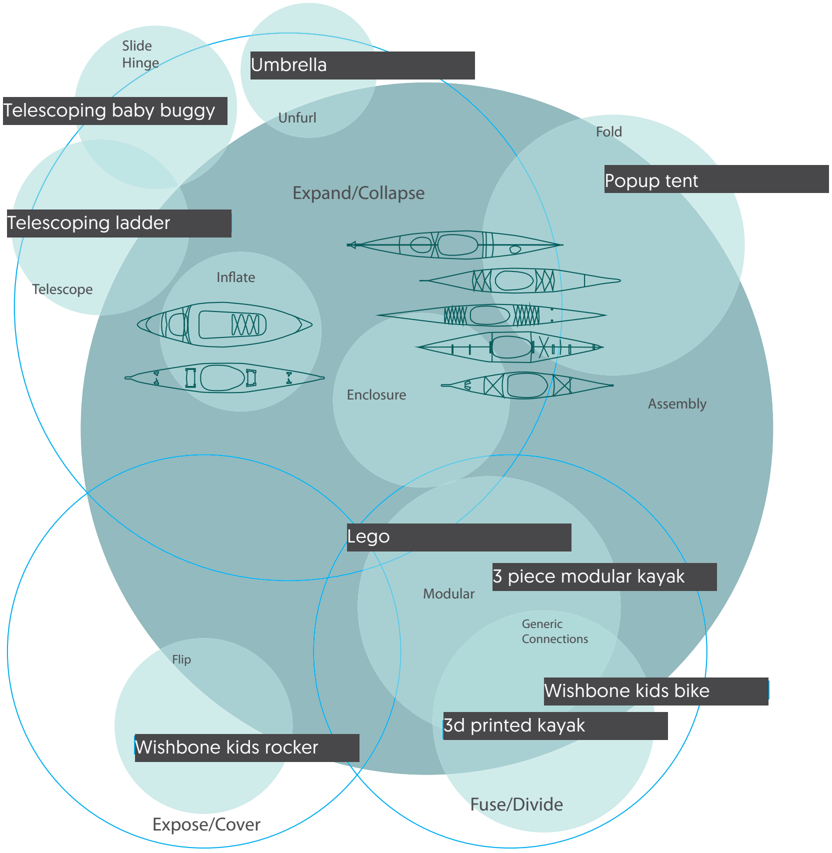


Figure 14a.

Using the Principles of the M.O.R.P.H. framework, exemplars identified from research were assigned to categories. All came under the category 'expand/collapse'. This category is generally used for products where size reduction is necessary. A wider variety of transforming systems and products that relied on modularity and reconfigurability [**Figure 14 and 14a**] were then examined and categorized under expose/cover and fuse/divide to create a more diverse analysis.

The first test compared manual deployment to automated deployment — **Figure 15**. The results of this test established that most current transforming kayaks were manually deployed, with inflatable systems being more automated. The cross section of other transforming products had a larger range, with some almost entirely automated. The manual products generally had multiple uses, i.e. Lego.

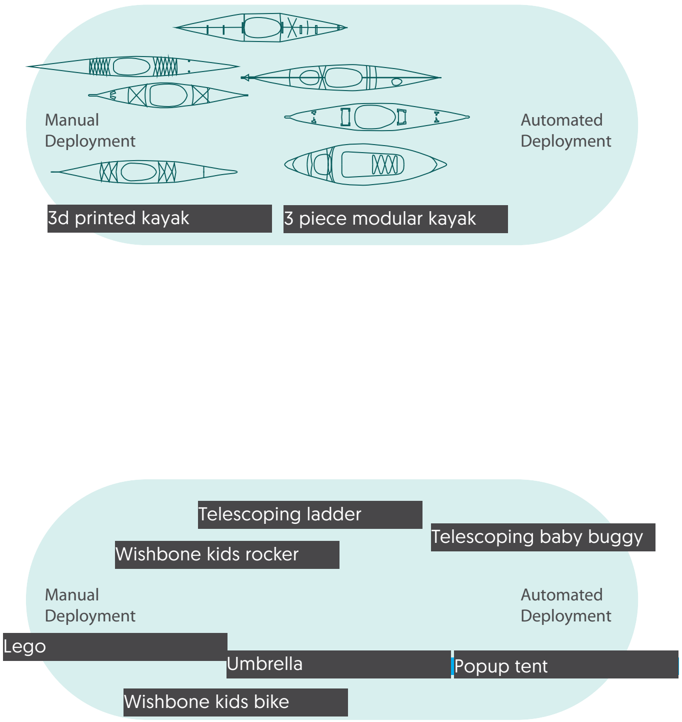


Figure 15. Comparison of manual versus automated deployment transforming systems in transforming kayaks, and products. Tests used the MORPH Transformation Framework categories established in figure 14.

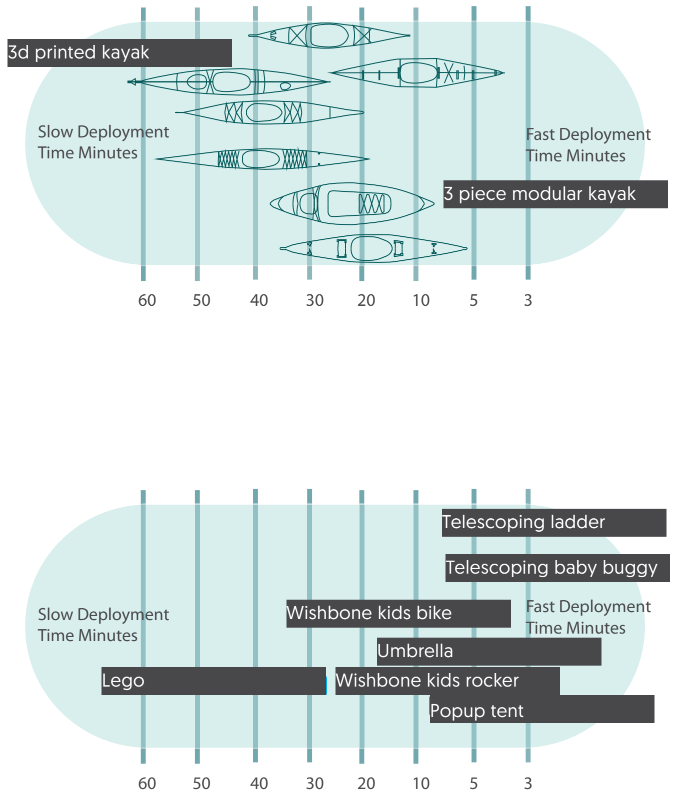


Figure 16. Comparison of deployment times of transforming kayaks, and products.

The next test compared the deployment times of kayaks to those of other transforming products — **Figure 16**.

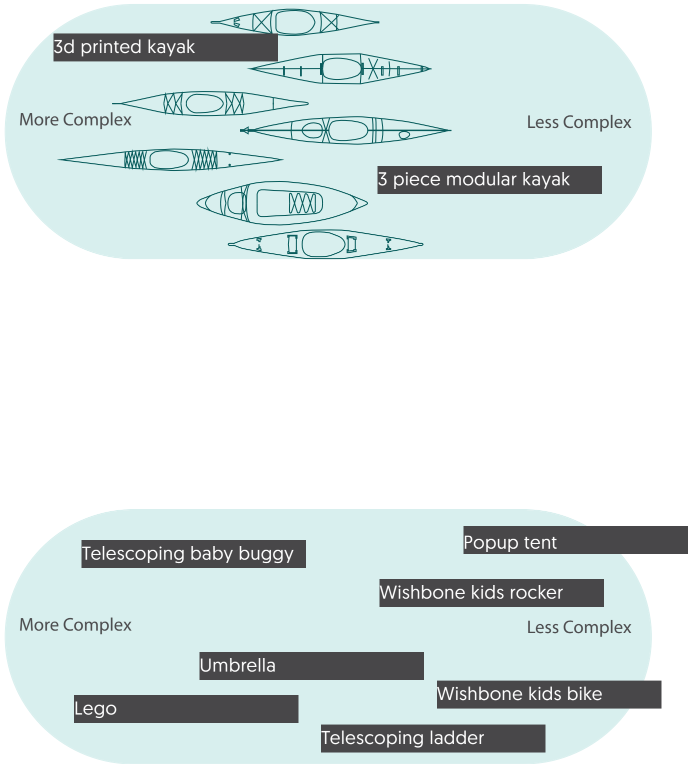


Figure 17. Comparison of complexity in transforming systems in transforming kayaks, and products.

Results showed that products with integrated components had much faster deployment times. This seemed to have little to do with the complexity of the product or system, but was further compared against complexity in **Figure 17**.

The final test compared the speed of M.O.R.P.H. facilitators in the deployment of kayaks and other transforming products. Results showed the fastest facilitators were fold, unfurl/unfold, and telescope. It was difficult to separate the facilitator from the system, and was likely that the fastest facilitators were a result of a well-designed system with integrated parts using the most relevant facilitator and correct materials. Results specifically for the transforming kayaks show inflate to be the fastest facilitator, likely due to significantly less assembly. The combined tests are summarised into a table **Figure 18**.

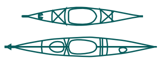
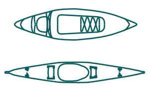
	System Type Mech/Mat	Levels of function/ Description	Trigger Y/N Type	Principle	Facilitator	Deploy mins	Assembly Complexity	Assembly Semantics
3d printed kayak	Fixings Mech	1 3d Print	N	Fuse/ Divide	Modular	>60	8	Cohesive
	Push Fit/lock Mech	2 Transport/Store	N	Expand/ Collapse	Fold	>40	8	varied
	Push Fit/ Lock Mech Pressure	2 Transport/Store	N	Expand/ Collapse	Fold Inflate	>40	8	Varied
	Multiple Mat	2 Transport/Store	N	Expand/ Collapse	Fold	>20		Varied
3 piece modular kayak	Fixings Mech	2 Transport/Store	N	Fuse/ Divide	Modular	>10	3	Cohesive
	Pressure Mat	2 Transport/Store	N	Expand Collapse	Inflate	>15	2	Cohesive
	Push Fit/ Lock Mech	2 Transport/Store	N	Expand/ Collapse	Fold	>45	7	Varied
	Slot, Memory Mat	2 flat pack	N	Expand/ Collapse	Fold	>15	5	Cohesive
Telescoping ladder	Locking/Sliding Mech	2 Transport/Store	Y	Fuse/ Divide	Telescope	>1	2	Cohesive
Wishbone kids bike	Fixings Mech	2 Grow/Skill	N	Fuse/ Divide	Flip	>6	3	Y
Wishbone kids rocker	Fixings Mech	2 Grow/skill	N	Fuse/ Divide	Flip	>10	4	Y
Popup tent	Spring tension Memory Material	2 Transport/Store	Y	Expand/ Collapse	Fold	>4	3	N/A
Telescoping baby buggy	Locking/Sliding Mech	2 Transport/Store	Y	Expand/ Collapse	Telescope Slide	>30sec	2	N/A
Lego	Push Fit Mech	2 Create/Learn	Y	Fuse/ Divide	Modular	Variable	3>	Cohesive Variable

Figure 18. Summary of combined tests, figures 14-17. The table highlights the problems and design opportunities of transforming kayaks.

The first notable discovery was the faster deployment time of products that had a point of contact or interaction to govern the system and initiate the transformation. By making this discovery, a new addition was added to the design criteria which, for the purpose of this study, is referred to as the 'trigger'. The trigger is not a recognised feature of the M.O.R.P.H. framework; however, it does have potential to be considered in future product transformation design as an enabler. A trigger removes the setup complexity by allowing a single point of contact rather than multiple complex points of contact inherent in most assembled transformation products. The Origami baby buggy in the product comparison has a trigger initiating a mechanical system, whereas the transforming kayaks have no trigger and rely on time-consuming assembly. This creates a larger learning curve and requires more time to deploy. (The exceptions were inflatable kayaks, which had a central point of inflation but a slow manual deployment.) The trigger can be aided by the level of automation as is evident in the pop-up tent. The tent does not necessarily have a focused trigger, maybe a strap or the bag that holds the tent under tension, with the material memory automating deployment once out of the bag.

Results showed there is little, if any, automation in transforming kayak setup. The Oru kayak does reduce complexity through a material folding system, but the system does not utilise material memory.

It was interesting to note that none of the kayaks took advantage of a transforming system to adapt the function of the kayak to suit a kayaker's ability or needs. All kayaks had two states; either deployed and active, or packaged and passive. While it is not considered necessary to have multiple functionality, the systems had no way to adapt length or width for the user. The Wishbone Rocker has a unique hybrid functionality designed around the growth of a child. The rocker uses flip as its facilitator, turning a baby's rocker into a toddler's push car. The effect of this variable is product longevity through removing redundancy, allowing the product to adapt and grow with the child. The simplicity of the design is achieved through a single facilitator, and without 'function creep' — a term used to describe well intentioned functions that are not used due to poor interpretation of user needs rather than actual needs (Humphrey, 1999, p. 18). Adaptability could remove barriers in transforming kayaks by changing a kayak's features relative to use, weather conditions, or a kayaker's skill or body type.

The frustrations of setting up and packing down a transforming kayak relate directly to the primary factor established as time. Survey respondents shared their most frustrating problems concerning the process — **Figure 19**.

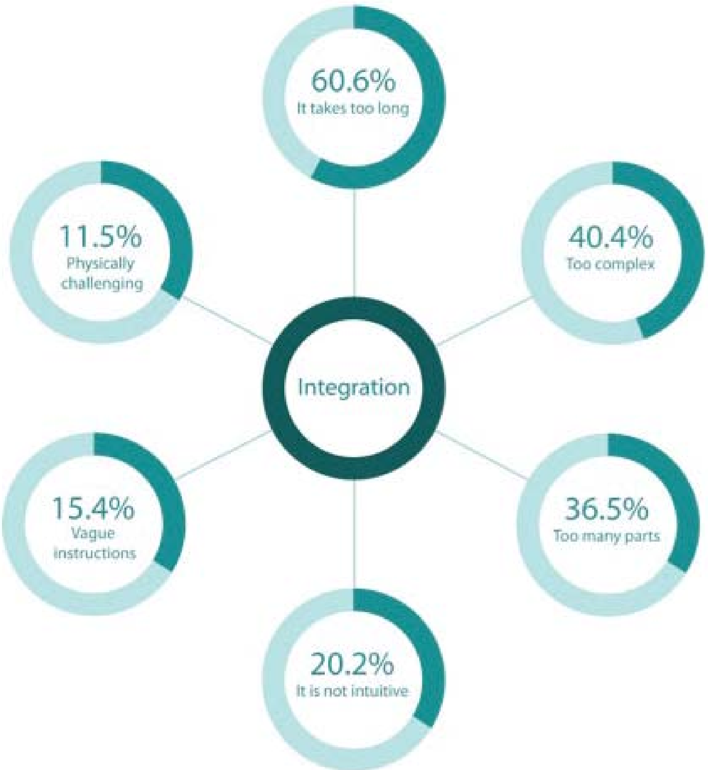


Figure 19. Kayaking Experience Survey respondents setup and pack-down frustrations. The graph highlights how integration could resolve many of the barriers.

Having researched other successful transforming products, I came to the conclusion that most of these frustrations could be resolved through the use of an integrated system. An integrated system removes assembly and should be a less complex process. It is expected that with an intuitive integrated system there should be no difficult physical challenge to the setup, nor should there be any need for instructions.

The findings of this product and systems research, considered with the needs and desires of kayakers and their lifestyles, highlight challenges and opportunities where design could remove barriers to participation. This was developed into the design criteria outlined in the following chapter.

4.0 Design Criteria

This section translates the research findings into a criteria to be applied to the new transforming kayak designs. *The Mayfield Handbook of Technical and Scientific Writing* describes the design criteria as “the explicit goals that a project must achieve in order to be successful”(The McGraw-Hill Companies, 2001, para. 2).

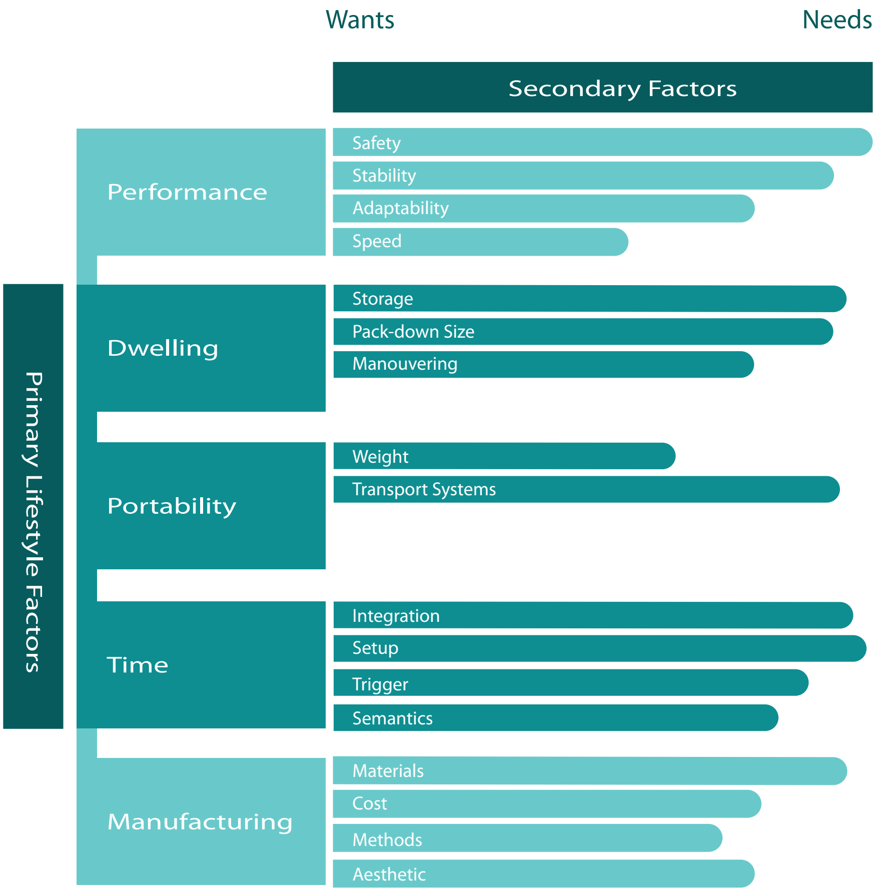


Figure 20. Design Criteria. The diagram shows the primary and secondary factors that were used as design directives.

The design criteria brings together the user research and the context review in the form of a diagram — **Figure 20**. The criteria lists the interrelated primary lifestyle factors as well as performance and manufacturing factors. It then lists the more explicit secondary factors where design needs to be focused. The design criteria was used as reference and reflection in design direction and decisions, but is in no way a complete list of every design goal. To expand on the design criteria a brief description of the goals is shown in **Appendix 9.6.**

5.0 Designing the Kayaks

This section is a critical reflection of the design journey. The design process was not linear, but occurred parallel to the user research and context reviews. This chapter connects the design criteria and all sources of collective previous research to the potential design solutions aiming to remove barriers to kayaking.

For each model the design was initially created in a full-scale digital environment. Virtual testing and critical analysis helped to accurately inform all the physical prototyping in this study, turning "data into things and things into data"(Gershenfeld, 2012, p. 57). Throughout the design I worked in a 1:5 scale for exploring form variations.

Preliminary ergonomics for all designs were tested in a virtual environment. Digital human models were created with population data averages obtained from *Measure Of Man and Women* (Tilley & Dreyfuss, 2001). This sped up the physical prototyping but wasn't a substitute for the dynamic movement of real people through testing at full-scale.

Virtual hydrostatics testing proved effective in helping to understand the stability of the kayak in the water while stationary, and the stability of the waterline once water displacement occurs from the kayaker's weight. Even small changes in weight and distribution affected kayak performance. Orca 3d, a computer modelling and hydrostatics programme used for boats, was used to validate the hull designs.

The design map (**Figure 21**) is a representation of the design journey and shows the evolution of design developed through this study.

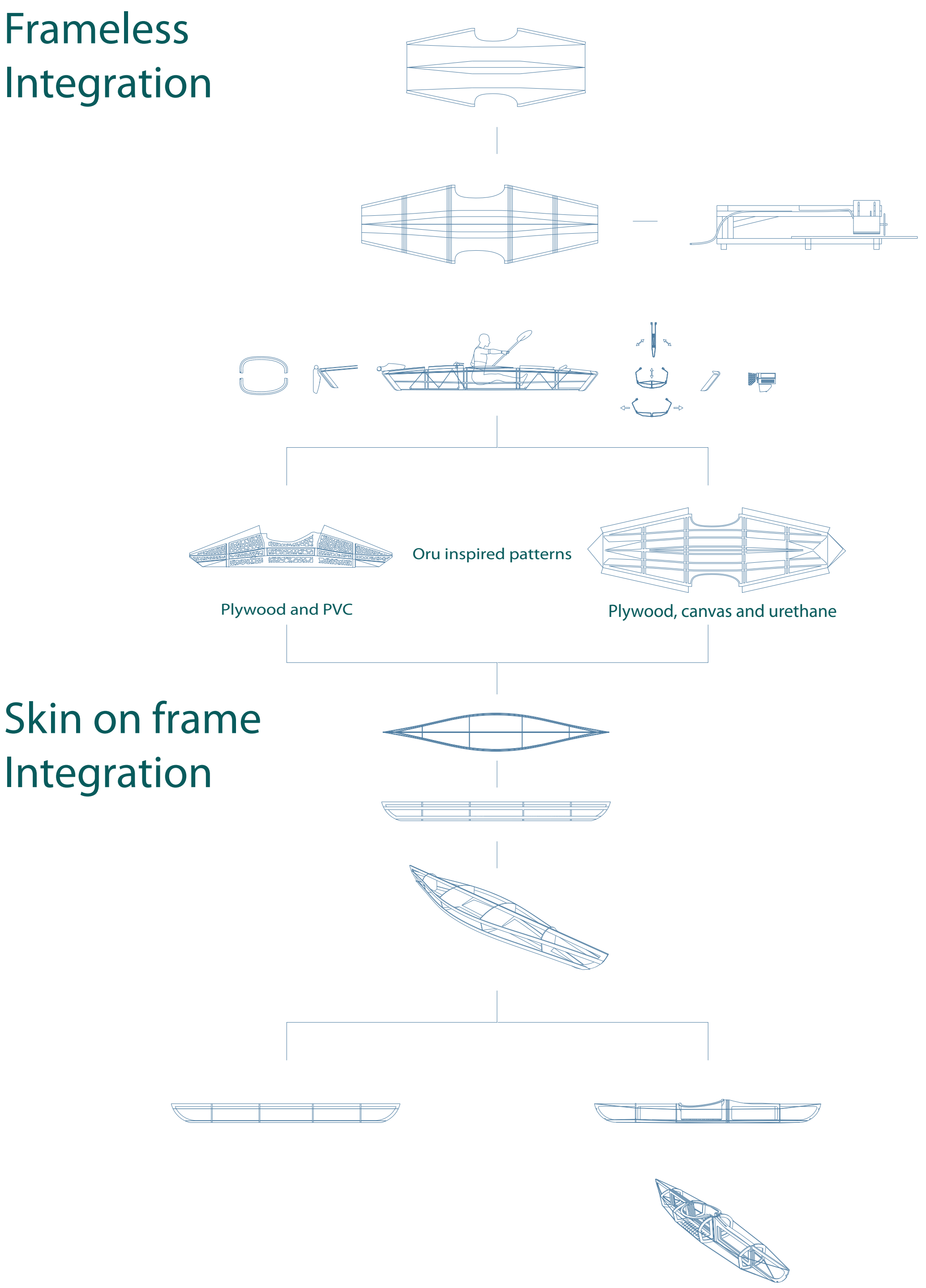


Figure 21. The design journey of integrating kayaks.

5.1 Frameless — Sheet-to-Form

Figure 21 shows two distinct categories that were explored. The frameless kayaks are without an internal physical structure, while skin-on-frame kayaks have a flexible skin over a frame. These kayaks are themed by use of the M.O.R.P.H. framework facilitators, using fold and slide as catalysts to begin exploring design.

I wanted the design to be both evolutionary and revolutionary, evolving current market kayaks through designing integrated systems. Being innovative meant finding the balance between what is still recognisable as a kayak, and something that is truly different. Some early pattern exploration produced shapes that were possibly too radical to be categorised as kayaks. Wydra and McElroy (2004) of Socratic Technologies, a product research firm, believe moving too far from what is recognisable can blunt acceptance and lose trust, a phenomenon known as preference inertia. “Preference inertia, in simple terms, is the degree to which the philosophy of “the devil you know is better than the devil you don’t know” prevents the target customer population from trying new things”. (Wydra & MacElroy, 2004, para. 4)

5.2 The Pop Out Kayak

The maker community’s experimentation with DIY kayaks first caught my attention with their use of fluted polypropylene sheet material generally used in signage and packaging industries. This material is lightweight and structurally stiff, properties that ticked the boxes for a more portable design. It also has the advantage of being a polyolefin, meaning it has excellent chemical resistance, is hydrophobic (rejects water), self-lubricating (low friction on the water), and, most importantly, performs well where a crease in the material acts as a living hinge. A similar material is claimed by Oru Kayaks to have "20,000+ folds" before potential failure — more than enough for a lifetime of kayaking ('FAQ | Durability Performance Portability,' n.d.)

During the exploration of this material I returned to the design criteria to guide me towards new solutions to help overcome the lifestyle barriers identified.

Some way into pattern exploration I was alerted to a crowd sourced 'Kickstarter' campaign for a transforming kayak called 'Oru' designed by Anton Willis. Oru was a well-executed design, neatly packaged, and validated through a successful crowd funding campaign. The Oru had already resolved what I had been attempting. What could I add? I had two choices: revisit the idea of sheet to form completely, exploring a different line of experimentation, or build on the Oru design, modifying the pattern with what I had already learnt, designing and integrating components and creating a faster system for deployment. **Figure 23** shows different model variations experimenting with paper patterns.

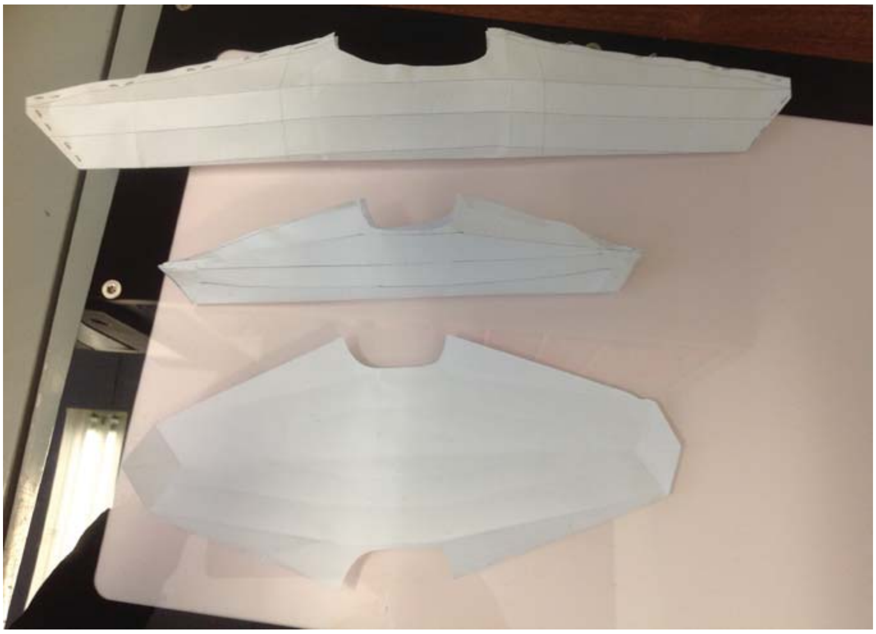


Figure 23. Iterations of paper kayak patterns. Early paper prototypes to understand pattern and material response, combining the Oru with my pattern ideas.

Analysing the Oru kayak against my criteria revealed several issues that did not address the lifestyle factors identified in my research. **Figure 24** highlights the design opportunities to be learnt from the Oru.

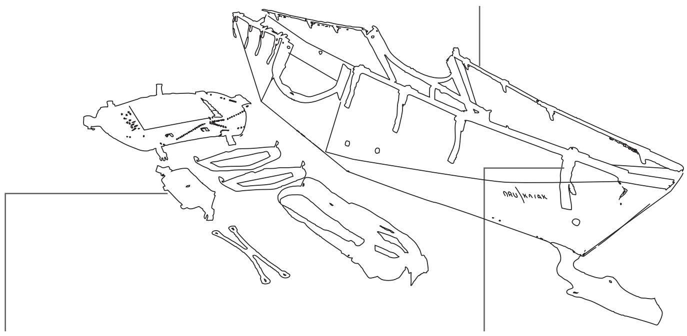


Figure 24. Problems and design opportunities to be learnt from the Oru Kayak.

Working with fluted polypropylene the material had a considerable amount of memory and required some force to press it into shape, the translation from paper to fluted polypropylene had completely changed how my pattern responded. Unlike the patterns I was originally working with the Oru used pleats to ease material tension and to create the curve (rocker) of the keel. I approached it from a different perspective questioning whether I could use the energy in the material from forcing the fold to my advantage. My aim was to remove the internal frame and transfer the structural integrity to the skin, thus effectively creating just a shell.

After trying a variety of systems that would aide in the transformation I drew reference from my boat design experience using 'Archimedes Principle' or block and tackle to force the kayak into shape. **Figure 25** shows Archimedes principle.

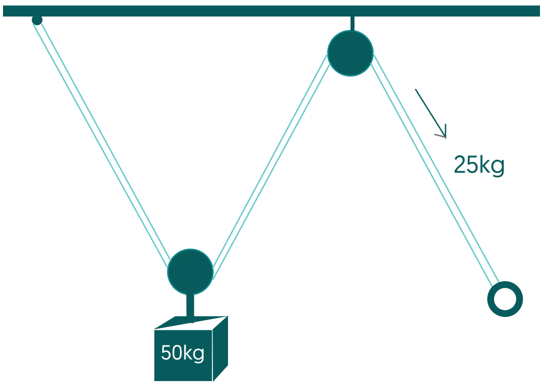


Figure 25. Archimedes Principle of levers example. The principle was applied to the transformation system.

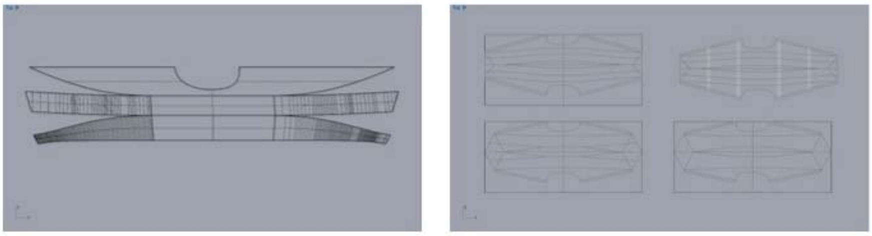
The scale-prototypes exploring the design had potential, the system addressed many of the lifestyle factors identified as barriers to participation. Primarily, removing assembly and adding a trigger to initiate deployment. This system relied on a completely different approach than the Oru kayak, closing it permanently at the deck seam with a central spine for stiffness and to hold the pulleys. This completely removed the need for connecting the deck seam every time for setup. As the cable was pulled and tightened, the deck and hull came closer together pushing out and flexing the side walls (chines), holding it in a state of tension. As the sheet was permanently closed the kayak was folded externally. **Figures 26, 27 and 28** show the 1:5 scale setup.

Figure 26. Deploying the first scale polypropylene prototype. The sequence highlights how the pulley system works.

Figure 27. The trigger

Figure 28. The cable pulls the kayak into shape.

This took less than a minute, which was fourteen minutes faster than the quickest reported setup time from survey respondent data, but was not yet known how this might translate to full scale. **Figure 29** shows a screenshot of the initial digital pattern and **Figure 30** shows analyses of the waterline and model for hydrostatics, the same model was used to test early virtual ergonomics.



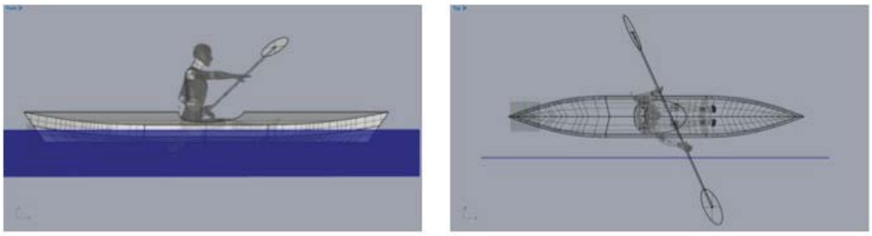


Figure 29 and 30. Screenshots of digital patterns and models. The images capture the working environment using the CAD software Rhinoceros for virtual analysis.

To make the full scale four-metre long kayak, 4000mm x 1800mm fluted polypropylene sheets were imported from Australia. The 8mm thickness created enough structural stiffness, and potential energy through stiffer folds, so the kayak would be under tension when deployed. **Figure 31** provides a cross-section of the numerous tests undertaken to press the material manually.

Working with this material raised some challenges. It was difficult to provide enough force to crush the flutes and create fold lines in the material. The material had considerable memory so once pressed it sprang back close to its original form. There were no local CNC beds able to accommodate the 4 metre sheet, so, as I couldn't find a tool to press the material, I decided to create one.

Figure 31. Example of polypropylene material test. The series shows a range of different tooling tests to press the fold lines.

I built a machine that had enough strength to press the folds into the material —**Figure 32**. During this process I learned how to control the fold width can affect the kayak's deployment.

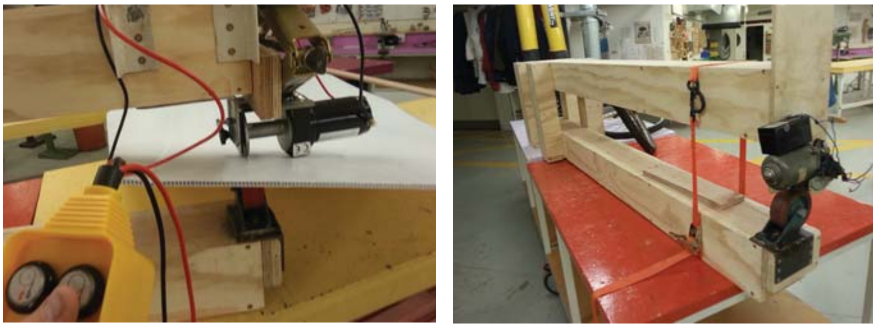


Figure 32. Prototype tool for pressing polypropylene sheet material. The machine uses a jack to create the correct pressure with a wheel and winch motor to guide and control the press.

Figure 33 shows how the removable wheel allowed for adjustable fold line width. Adjusting the width of the fold lines made a difference to the energy required to fold the material, and also the angle to which it could be folded — **Figure 34**.

Figure 33. Adjustable press wheel for fold line width.

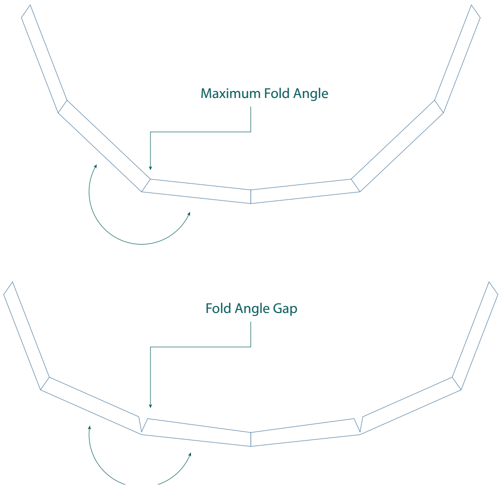


Figure 34. Sensitivity of the fold angle. Adjusting the gap can control the angle to which it is folded.

This was an advantage in controlling how far the kayak skin would bend before it was impeded, and the force it would take to actually bend it. If the kayak was too physically challenging to deploy, I would be potentially excluding some kayakers. With 11.5% of my survey respondents already finding setting up a transforming kayak physically difficult, setup needed to remove the physical effort.

Next I created my first full size prototype using the machine I had built. The design utilised as much of the waste sheet material as possible, thus minimising fabrication parts and processes. The pulley trigger was easily accessed from the cockpit, with one point of contact being a big advantage over current transforming kayaks. Consistent visual and functional language meant a ratchet connecting to a pulley was the most appropriate trigger for this design. This trigger meant less physical force was required for the stainless steel cable to pull the kayak into shape — **Figure 35**. The deployment system — **Figure 36**.

The deck seam support resembled a spine — in a way paying homage to Theroux's (2003) previously quoted foreword where he describes the folding kayak as having more in common with an animal than a boat (p. 2). It truly did feel like it was taking on anatomical characteristics; an articulated spine, skin, and a cable acting as muscles and nerves. With this in mind the kayak needed to be released into the wild, ready for testing in the environment for which it was intended.

Figure 35. The trigger initiating and controlling the setup. A simple geared strap ratchet was used as a proof of concept in prototyping to wind the cable and create the tension to deploy the kayak.

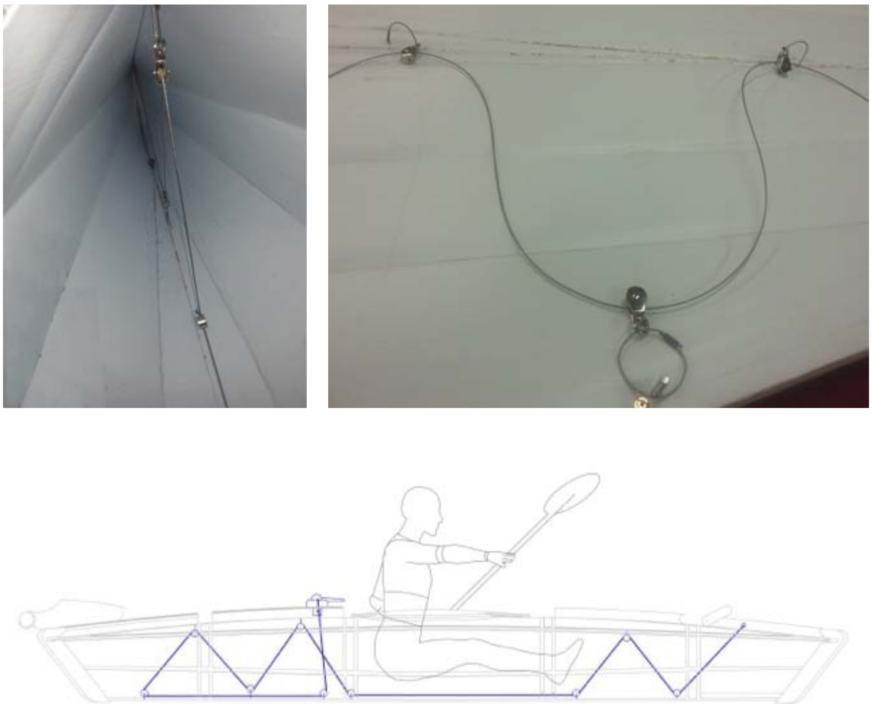


Figure 36. The cable and pulley system.

5.2.1 Pop Out Prototype Sea Trial

The Pop Out prototype sea trial tested transportability, setup, pack-down, stability, entry and exit, and paddle performance. **Figure 37** captures the sequence of events as it is described in this section.

Findings from the first Pop Out kayak sea trial showed that this kayak rated well for portability, fitting into the car boot and easily carried down to the water. Setup was quicker than expected at less than one minute. This was 29 minutes faster than the average deployment time of current transforming kayaks.

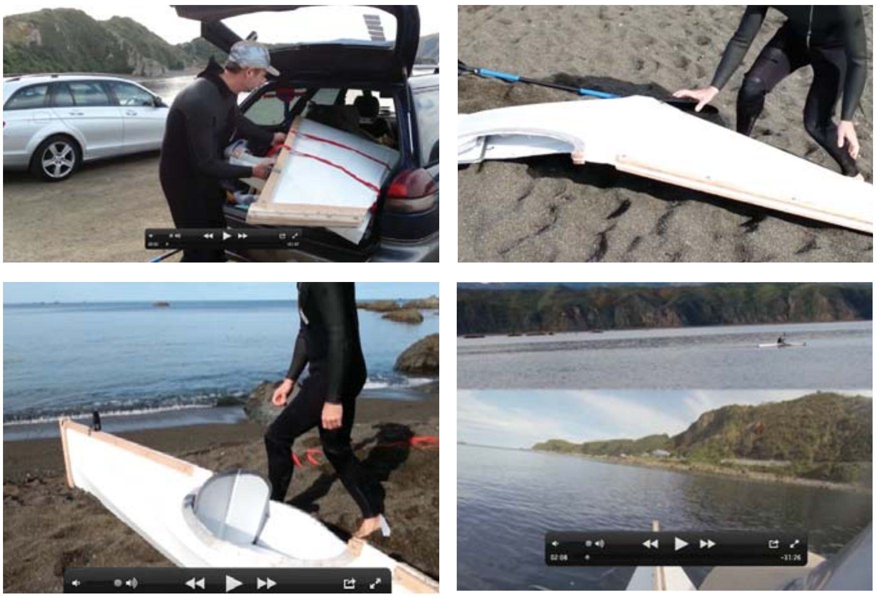


Figure 37. Sea trial testing the system.

Its speed was excellent — on par with race focused kayaks, however a steeper hull angle than the Oru made it less stable. It tracked well but did not manoeuvre easily without a rudder. A flatter bottom on the kayak would offer better manoeuvrability and stability but would increase its flexibility.

This light fast kayak performed more like a race kayak than an adventure or touring kayak. Current transforming kayaks have been widely criticised for their lack of speed (Bigelow, 2008; Jones, 2000), and no transforming race kayaks currently exist on the market. This raises exciting possibilities. But although this prototype had potential, it was not enabling a wide variety of users, appealing to more niche advanced and race focused kayakers.

It was near the end of the sea trial that an unexpected discovery was made. It occurred to me that over-tensioning the cable may impact the beam (width) of the kayak, effectively making it more stable. I didn't even need to exit the water to make the adjustment, just reach back and crank the ratchet. As a result, the hull and deck moved a bit closer together, and in doing so pushed the sides of the kayak out further. This increased the overall beam, and in turn increased the kayak's stability, as depicted in the diagram **Figure 38**. This did create a minor change to the seating position, but the adaptability was more than enough compensation for less than perfect ergonomics.

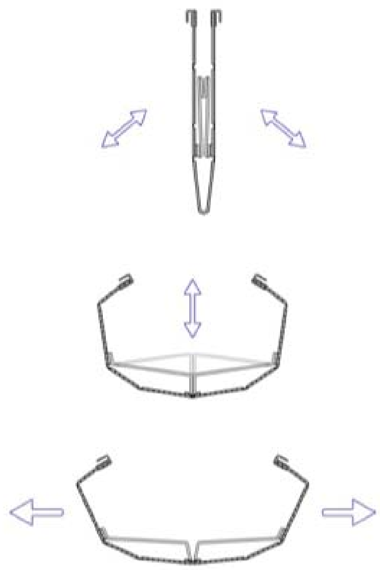


Figure 38. Diagram of how adjusting the beam (width) controls the kayaks stability.

This was the adaptable function that I had been hoping for. Never before seen in a kayak, this function could overcome some of the performance barriers revealed in my research. It could give the kayaker control over performance and stability if the water became rough, or if the paddler was less skilled or confident. The kayak could effectively grow with the skill and changing needs of the paddler, negating the need to own multiple kayaks to suit different circumstances and paddlers.

Post sea trial I needed to integrate all the components into one functioning kayak, developing the discoveries from the sea trial, and further looking at how the components could add extra functionality and further enable kayakers.

To this end, I built a second Pop Out Kayak. Integrating all components to one transforming system including seat, cockpit rim, rudder and steering pedals. The components were design projects themselves, all had to function but also nest into the body of the kayak when packed. For the rudder hinge the polypropylene memory had the advantage of tracking straight and returning to a neutral position when paddled in a straight line. This was a new innovation in kayak rudders and something not included on the Oru — **Figure 39**.

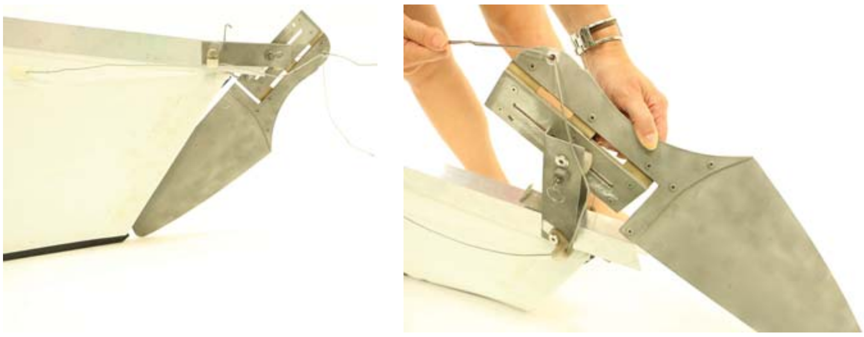


Figure 39. The rudder nests away for pack down, when deployed the amount of rudder in the water can be adjusted. The material hinge returns to neutral for tracking straight.

Figure 40. Foot rests and rudder steering pedals, from left to right: 1. The adjustable mechanism for low volume pack down. 2. The foot pedals with padding it pops up from flat. The nested position of the peddles for pack down.

The trigger changed from a ratchet system to a pull system, speeding up set up time. Waste material was utilised for the seat and foot pedal components. The foot pedals were adjustable to adapt to a paddler's height and paddle position, as illustrated in **Figure 40**.

Figure 41. The polycarbonate cockpit rim. The cockpit rim is used to attach a sprayskirt and to stiffen the area around the cockpit for entry and exit.

The polycarbonate cockpit rim needed for the attachment of the spray skirt nested within the folded design. **Figure 41** shows the polycarbonate inside a fabric skin, with the idea that it would allow a moderate amount of flex.
The seat was constructed from the same sheet as the skin and worked as a safety backup for any possible cable failure by locking-out in an over-centre position —**Figure 42**.



Figure 42. The integrated seat slides to adjust for height. When deployed it locks out snapping into place.

To fix the cable without penetrating the hull, ultrasonic welding proved to be the best process to attach the lugs to the inner skin — **Figure 43**.

Testing load failure on the lugs is shown in **Figure 44**.

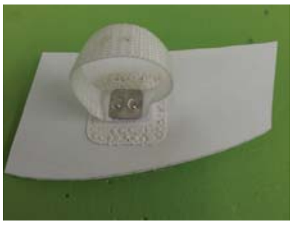
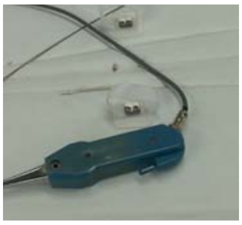




Figure 43. Ultrasonically welded lugs. The pulleys attach to the lugs, distributing the load.
Figure 44. Right. Load testing polypropylene pulley lugs.

Figure 45 shows the Pop Up kayak in its folded form, and **Figure 46** shows its deployed state. I now had a system; a proof of concept that ticked many of the boxes and would help overcome some barriers to kayaking, but the design needed to go further.

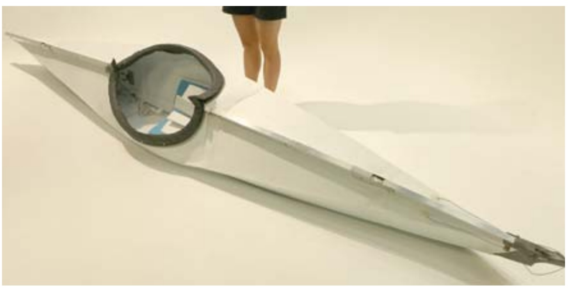



Figure 45 & 46. The 4m Pop Out kayak in its packed down and deployed states. The Oru inspired pattern is now fully integrated, complete with rudder, and foot peddles, setting up in under a minute.

5.3 Sheet to Form Variations

There was a pause and a point of reflection at this stage of the study. The process had come a long way towards integrating the components into a transforming system. The aim was to remove barriers to participation in kayaking and with time being the most important primary lifestyle factor this was achieved through a simple and efficient deployment system with integrated components.

The discoveries had significant potential, but the process did lack divergence in exploring a variety of new materials possibilities. The important innovation I was bringing to the evolution of the sheet to form was the deployment system. Polypropylene was an effective material, but could I design alternative solutions? I needed to Look for similar folding behaviours, allowing structure and flexibility in the one sheet, or in a composite of materials. This would add manufacturing alternatives to the way the kayak could be made and push the potential further.

5.3.1 Conjoining Materials

I started by exploring combining flexible and stiff materials in a composite sheet. The previous deployment system would transfer over with a similar pattern but adding pleats similar to the Oru. The pattern was laser cut from readily available marine plywood, then the gaps were filled with a liquid silicone to bond the plywood and promote flexibility through the fold lines, as shown in **Figure 47**.

This material combination resulted in less fluid lines along the outer shape of the kayak, and would require pattern modification. It would also be heavier that polypropylene in full scale, limiting portability and speed. As the sheet uses separate parts

Figure 47. Conjoined materials, plywood and silicone.

it could be cut using smaller CNC beds, or even shaped by hand tools. The clear silicone bonds were intriguing allowing some light transfer through the kayak and the plywood grain added a sense of value and craft missing from the polypropylene. As a bonding material silicone was far too weak and would likely need further thought, possibly replacing it with a urethane elastomer.

5.3.2 Borrowing from Tradition

The conjoined craft and material motivated me to push the idea further for the next sheet alternative. Inspiration came from the traditional designs of the stitch and glue, and skin-on-frame kayaks.

Figure 48. Saf, K. n.d. Stitch and Glue Canoe. Photograph. CC BY-SA 2.0,

Figure 49. Erwanlouet, I. n.d. Skin qajaq. Photograph. CC BY 2.5.

The stitch and glue kayak shown in **Figure 48** uses rope or zip ties to stitch plywood panels together, followed by waterproofing the seams on the inside with fibreglass tape. The skin-on-frame kayak utilises a waterproofed canvas skin over a wood frame as shown in **Figure 49**.

There is a timeless beauty to these designs; traditional materials and craftsmanship come together with simple fabrication techniques to create an aesthetic that many kayak builders seek to emulate. This design was a chance to borrow from the old and apply to the new.

Figure 50 and **50a** show the influences of the skin-on-frame design when applied to a sheet to form variation. With this design the aim was to provide semi-rigid panels and structure with the plywood while creating flexible fold lines through the gaps with the canvas skin. The plywood sheet was modified in the CAD programme Rhinoceros using panel tools to remove some of the material from the pattern. It was then laser cut allowing for a gap between fold lines and, keeping with tradition, plywood was used for the sheet structure while a cotton canvas provided the skin. This skin was bonded to the plywood and waterproofed

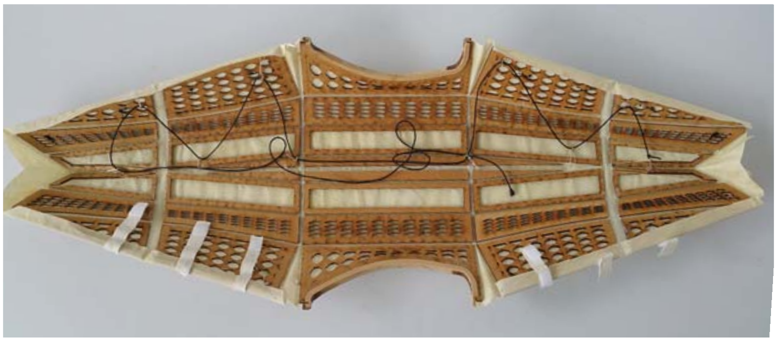


Figure 50 & 50a. The influence of the skin on frame kayak on the sheet to form. Waterproofed cotton canvas over plywood. The panel cut to emulate skin on frame kayaks.

with clear polyurethane. The same cable pulley system and trigger from the polypropylene kayak transferred across and was adopted into the transformation.

The resulting design was lighter and more portable, but did not have the structural integrity anticipated for a full scale kayak. The fold gap wasn't particularly accurate so I didn't have full control over the fold lines. However, the polyurethane applied to the canvas provided an unexpected transparency, shown in **Figure 51**, revealing the wood and allowing filtered light through the fold gaps creating an interesting aesthetic.

Figure 51. Transfer of light through the skin. Canvas over plywood frameless sheet to form alternative.

5.3.3 A Functional Aesthetic

Polypropylene provided less scope for the development of a bold aesthetic, but material combinations suddenly opened the way to express unique qualities. Traditionally transforming kayaks focused on function, with little to celebrate in terms of an aesthetic. In fact 55.9% of respondents from the Kayaking Experience Survey (2014) believe the aesthetic of transforming kayaks is a disadvantage in comparison to solid-state kayaks.

5.3.4 A Composite of Ideas

The next material alternative attempted to create an aesthetic to combine desirable and functional qualities. Weight was identified as an important secondary factor for portability, with only 42% of survey respondents believing weight to be an advantage in current transforming kayaks. Weight and structure are integral to performance, with a lighter kayak generally being a faster kayak. Borrowing from nature rather than tradition this time, I explored using Voronoi patterns to reduce the weight and play with the aesthetic. A Voronoi pattern generator in a CAD plugin called Grasshopper aided in resolving the issue, as seen in **Figure 52**.

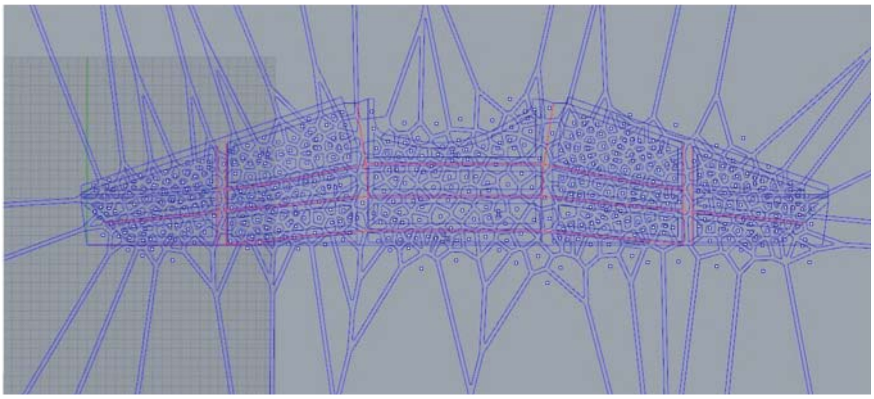


Figure 52. Creating A Voronoi pattern in Grasshopper. The Voronoi pattern is ubiquitous in nature, the randomised pattern minimises weak points in the structure.

The advantages of using a generative Voronoi pattern included reducing the weight, while keeping most of the structural integrity. The randomised patterns spread to structurally minimise points of weakness thus creating a stronger kayak. Experimenting with different patterns to reduce the panel weight also improved the aesthetic to allow light patterns to filter into the kayak — **Figure 53**.

Figure 53. Voronoi light pattern on kayak.

The final sheet to form alternative was again influenced by tradition — looking at the design opportunities for a stitch and glue kayak, but also using a mix of contemporary and traditional materials. This design combined many of this study's previous sheet to-form discoveries.

Figure 54 shows features of this sheet to form Voronoi design influenced by stitch and glue kayaks. The combination of three materials — non-fluted polypropylene, plywood, and clear urethane sheet materials — created form and structure to further explore transparency and pattern in the aesthetic.

Figure 54. Frameless Clearcut voronoi.

Inspired by the Oru Kayak, the pattern was updated to add pleats to take the stress out of less flexible shell materials. The live hinging polypropylene was stitched to laser-cut plywood panels to complete the structure. Then the kayak was water-proofed with a clear urethane plastic sheet as a secondary outer skin.

The findings from this design with its many possible variables shows that it holds potential for overcoming portability and builds a unique aesthetic identified as missing in the research. Aesthetically, the stitch line of the join provides a detail that hints at a contemporary play on tradition and craft, and the clear skin allows a peek inside the kayak, bringing out the panel pattern while also framing the aquatic life visible below the water. While the Oru pattern worked reasonably well in the alternatives, future studies of composite sheet construction would need to provide new patterns to create different, more stable, or faster kayak forms to address lifestyle factors impacting participation.

5.4 Framed Kayaks – Fold and Slide

Having explored a number of sheet–to-form material designs, it was time to explore other systems. I wanted to incorporate the ideas of integration and zero assembly in an evolutionary top down approach to directly challenge the current most popular skin on frame transforming kayaks.

The current models have a slow and complex setup process, requiring assembly of the multi-part frame then attachment of the skin — **Figure 55**. The challenge was for the cage-like rigid frame to expand and collapse in one interconnected piece through both the length and width. No other skin on frame transforming kayak had integrated the skin into the design, opting instead to have the skin placed on the frame after construction.

I revisited the M.O.R.P.H. framework to consider other possible transformation facilitators. The successes and failures previously recognised in earlier design alternatives helped to inform this next stage of design.

Tackling transformation in two dimensions at the same time was proving complex. It began to dawn on me that although an integrated design would address many of the barriers to kayak participation, the complexity of mechanical transformation in multiple dimensions could be the reason why skin-on-frame transforming kayaks have not yet been developed.

Figure 55. Egorxe. 2009. Taimen3_assembly. Photograph.

There were many challenges to overcome in order to create a transforming frame. Skin-on-frame kayaks have lengthways stringers which are integral to the structure and shape of the frame; all of these stringers needed to pack down without the current method of being disassembled. Collisions between articulating components needed to be resolved, and the many articulating joints needed to lock into position. A way to fold the central frame while keeping a solid structure had to be devised. The many points of contact for deployment needed to be replaced by a trigger as the central control of deployment, and a way to integrate a well tensioned skin during transformation had to be devised.

Frames are relatively complex compared to sheet material. A mock up test model 1:5 scale frame was fabricated to experiment. I wanted to see what could be removed or added to the traditional frame to simplify the system. **Figure 56** shows an example of later CAD testing processes. Feedback from the virtual model gauged pack down size and accurately predicted potential collisions between articulating components.

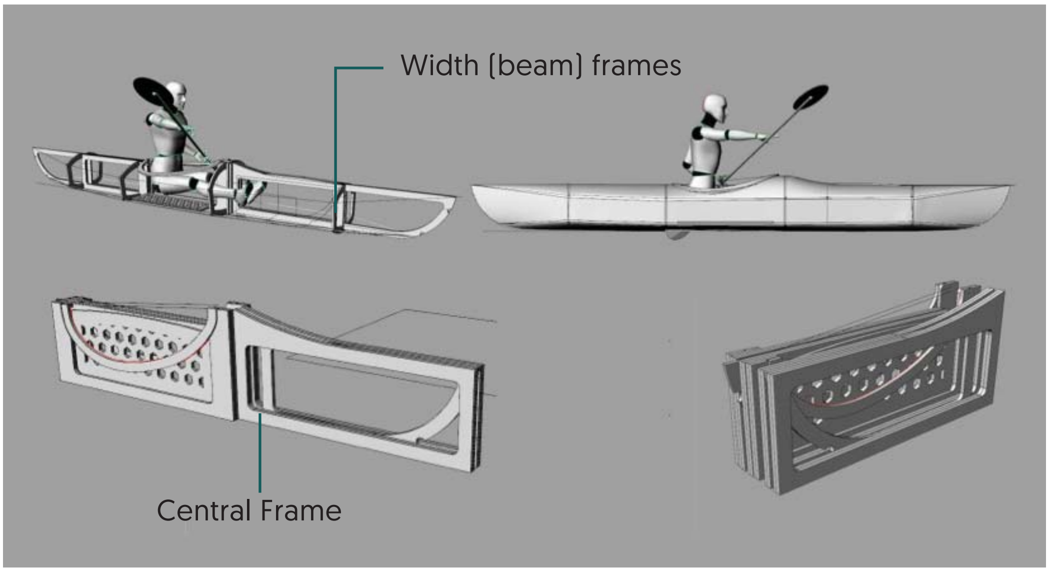
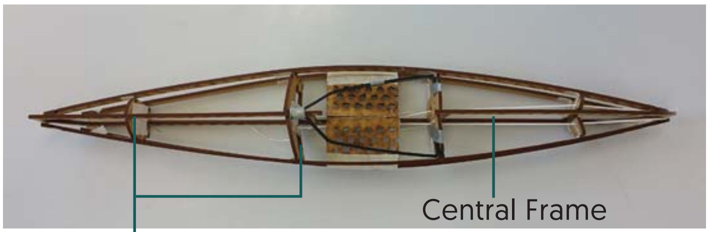


Figure 56. Simulating CAD models of frame systems during transformation. The models analysed the ergonomics, pack down and collisions of parts.

Figure 57 shows the scale model with bending stringers and width frames folding out. This worked well as a flat pack but it was difficult to resolve how the stringers and central frame could pack down to a shorter length. The cable system was adapted from the frameless kayaks to act as a trigger to pull the width (beam) frames out. The four stringers were secured at the bow and stern and forced the kayak into shape — **Figure 58**. With the complexity of trying to transform the stringers I instead removed the stringers and replaced them with cable; as the cable was pulled the width frames swung out tensioning the cable and



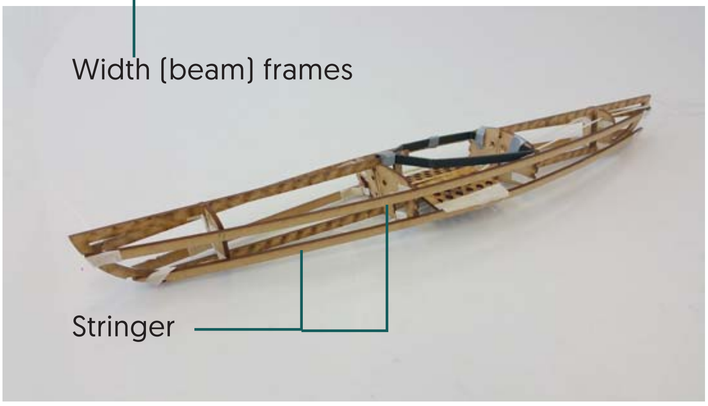


Figure 57 Top and left. Four central frames bend out the chines flat packing the kayak frame.
Figure 58 Bottom. The chines are secured at the bow and stern.

mimicking the structural integrity of the stringers. **Figure 59** shows the first trial in action. Replacing the stringers with the cable added something quite unique to the kayak's aesthetic, minimising both the physical and the visual weight. With the cables all but invisible from a distance, the kayak appeared to defy physics. I wanted to expose those qualities by giving the illusion of no skin rather than cover it up. The skin was already

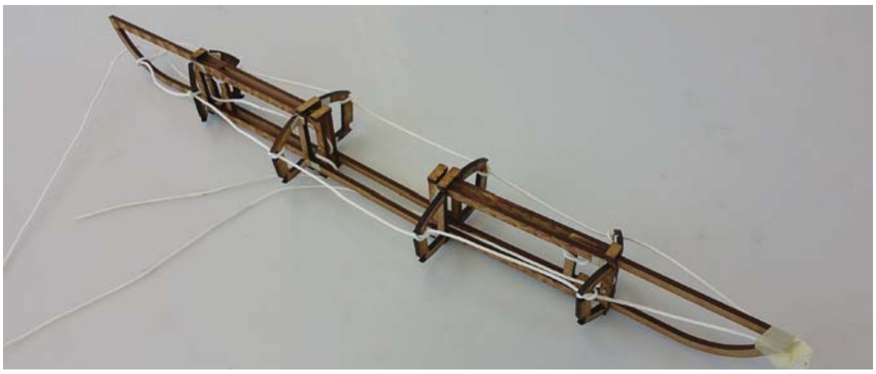


Figure 59. The chines replaced with cable. The cable would be tensioned allowing the skin to sit over the top.

at maximum stretch lengthways along the central frame and it needed to stretch even further when it was folded; the force this put on the skin was too much and resulted in tearing. I needed to find another facilitator that would help resolve these issues.

5.4.1 The Sliding Solution

Other M.O.R.P.H. framework facilitators did little to resolve the central frame issue. The solution came to me while taking a break. I watched a painter across the road set up a ladder that he unfolded once then extended to lengthen it. Although a very different intended function, the ladder itself was not so different from the central frame of the kayak I was designing. If the ladder was turned on its side it had central frame not dissimilar to the keel and deck line of the kayak. The facilitator that extended the ladder was a sliding action not too dissimilar to telescope in its linear trajectory. **Figure 60** shows a similar sliding extension ladder.

Figure 60. Ebbel, H, V. n.d. Leiter_ladder. Photograph.

Sliding was effective, but the kayak's pack-down size was still too large at 1300mm long. For portability it needed to fit into the average car boot and not be too cumbersome to carry or take on public transport. The extension ladder used dual facilitators of both slide and fold. Combined, they doubled the length of the ladder while also adding stability and the ability to be used as scaffolding. Working on physical models at 1:5 scale, a variety of designs were tweaked to achieve a system with a linear central frame.

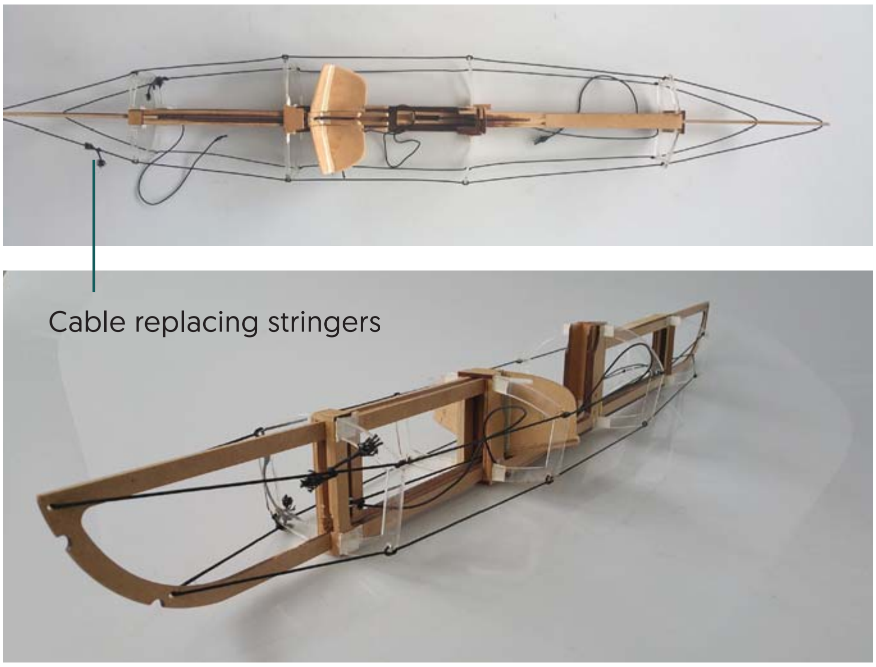


Figure 61. The deployed kayak using slide and fold facilitators.

The slide and fold design overcame many of the previous challenges. **Figure 61** shows how both facilitators complemented each other to achieve a longer, faster and more stable touring kayak of 5 metres. This design has a pack down length of 850mm which is smaller and more portable than previous frameless designs, meaning it can fit into smaller spaces such as the boot of a small car. The same cable acts as a trigger to pull the cross sectional frames out from the central frame and in doing so lengthens it. This cable through the central frame adjusts by

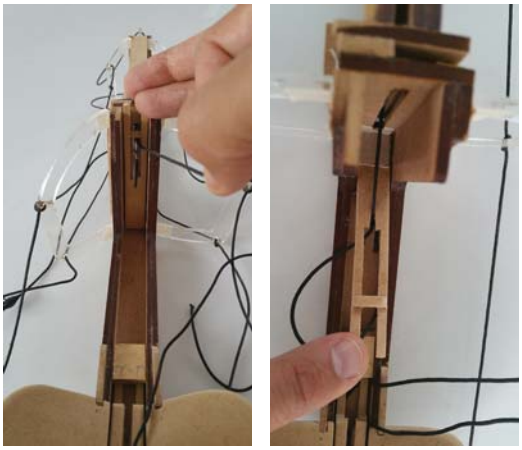


Figure 62. Over-centre tensioning and V-cleat. The over-centre lever provides extra tension to the cable.

hand to a marked point, then locks into a V-cleat on an over centre arm — **Figure 62**. The arm works as a lever to pull the cable tighter with less effort. **Figure 63** shows the folded internal structure with integrated seat back and pan folded down.

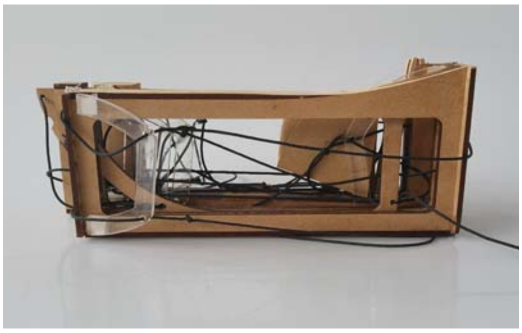


Figure 63 & 64. The kayak in its packed down state with all integrated parts nested together.

The cockpit rim remains attached to the skin in two halves, similar to the frameless design, and nests neatly to the sides of the frame when packaged, as shown in **Figure 64**. A robust clear urethane skin allows a view of the sea life below the surface of the water. **Figure 65** displays the 1:5 scale model with the clear skin.

Findings of the slide and fold design were edifying. I discovered

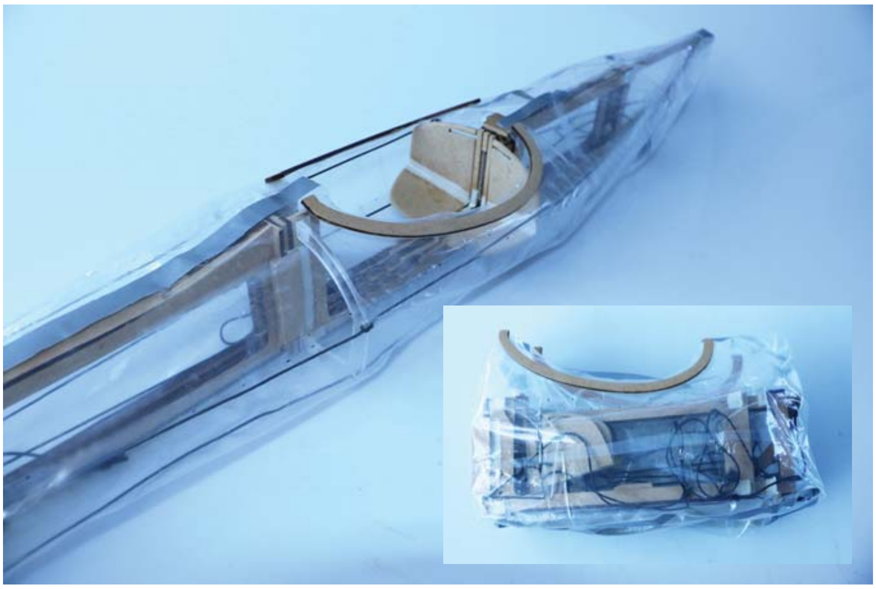


Figure 65. Kayak with clear skin deployed and packed down.

that changing just the cross sectional frames in the digital cut-file provided control over the shape of the kayak. I decided on a flatter hull for greater stability, potentially encouraging a wider range of skill levels and experience. While this would have some effect on speed, it also meant the kayak would turn more easily and not necessarily require a rudder.

The cable system needed to be under considerable tension both to brace the central frame and to hold its shape with the skin on top; this could be an inhibitor for the secondary factor setup as some kayakers may not be strong enough to get the required tension it would likely need at full-scale. Once in position the cockpit rim and seat added stiffness and structural integrity to the kayak for safety.

Using slide as a facilitator resolved the problems encountered earlier with the skin stretching and tearing when folded. When the central frame was reduced in length, the skin had adequate slack to accommodate the single fold in the frame. The skin was more than a watertight barrier separating the paddler from the elements; it was integral to the aesthetic. Earlier prototypes hinted at the internal structure, adding intrigue and curiosity to

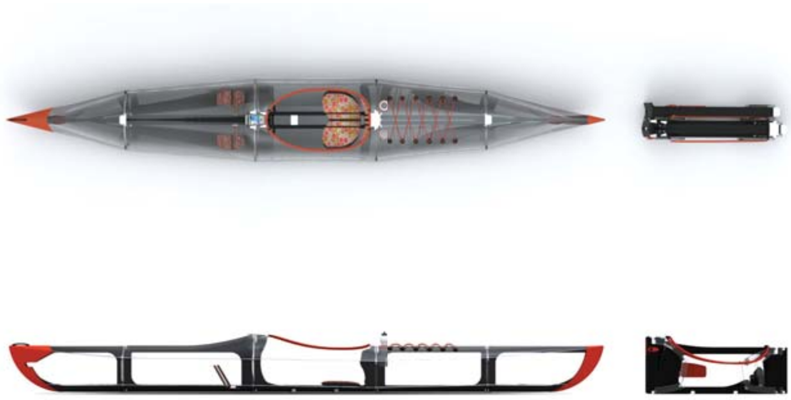


Figure 66. Digital Representation of the final composite sliding kayak.

the design. A clear skin offers more than a celebration of the design; it also brings the kayaker closer to the environment.

Research and prototyping represented usability and utility, but developing detail was necessary to represent the final vision and portray the aesthetic qualities of the kayak. Although desirability is not solely represented on an object's aesthetic qualities, I still wanted to end this phase of exploration with a vision of future development. To build this vision I chose the skin on frame kayak with composite construction modelled in Rhinoceros and rendered in Bunkspeed Pro. **Figure 66** and **67** show the aesthetic representation of the skin-on-frame kayak.

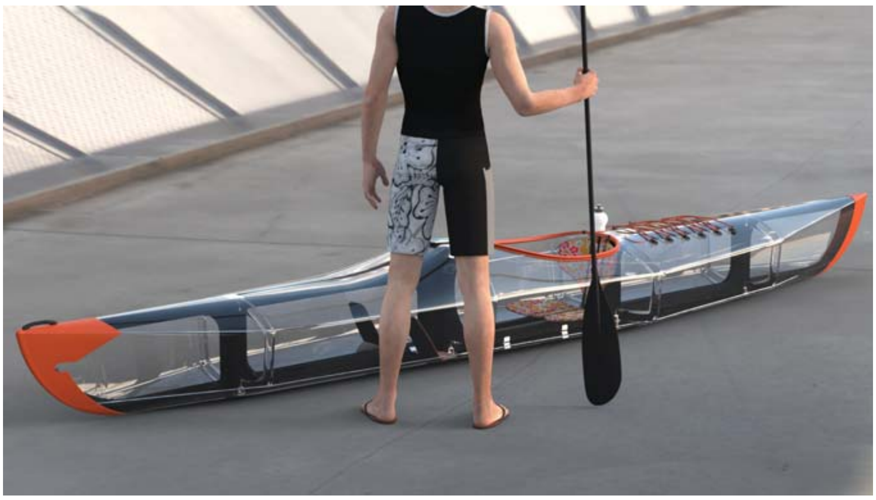


Figure 67. Digital Representation of the deployed composite sliding kayak.

6.0 Conclusion

Through a design-led process I set out to explore transforming kayak designs that could remove the barriers to kayaking. I wanted people to have the opportunity to participate regardless of where they live, whatever transport they used, or how much time they had available to them. I wanted to explore how transformation, or, more specifically, the transforming kayak, could empower those who didn't have the opportunity to kayak and overcome those factors inhibiting their ability to enjoy kayaking.

I believed the lifestyle factors identified as barriers to participation could be overcome through the design of improved kayak systems. I believed that transforming systems could allow the kayak to adapt to meet needs not being met through current transforming kayak designs.

In starting out there was a certain naivety about the complexity of integrating kayaks without assembling parts. Reflecting on the evolution of the transforming kayak from its inception to its present manifestation, it is now easier to understand why the integration of all kayak components had not evolved despite having many benefits. Designing an integrated transforming kayak set off chain reactions in the design: the changes I made in one area affected everything that connected, moved, or nested, requiring constant revisiting of each decision. Any decision made in the design process needs to be calculated well in advance, taking into consideration what affect it will have on the rest of the design.

The intention was always about potential: an exploratory design project with an outcome that produced a series of transforming kayak systems to address lifestyle factors inhibiting ownership and participation. The resulting designs provide possible solutions to overcoming the majority of inhibiting lifestyle and performance factors identified as preventing people from kayaking.

The body of knowledge from this study adds to the evolution of the transforming kayak through the integration of exemplars.

Initially I anticipated a series of working prototypes, but I didn't anticipate the true complexity of the project. Integration had a big part to play in the complexity, but research pointed towards integration as the key to addressing many of the lifestyle factors identified. It was the realisation that I was too focused on one style of kayak that lead to more divergent exploration and discovery. Upon reflection, this worked in favour of the design process. The initial proof of concept created knowledge, ideas and innovations that opened the way for other related ideas and possibilities. This was the face of potential; a tangible, measurable outcome that then set a precedent against which other ideas could be measured, without the need to develop full-scale working prototypes for each system.

6.1 Addressing the Questions

Three questions were posed in the introduction. The first question asked whether new transforming designs could remove the barriers to kayaking. I will show how these designs help to overcome the barriers to participation. The influencing lifestyle factors needed to be known to inform the possible design solutions. Other transforming design opportunities needed to be identified to inform the design.

To understand the lifestyle factors that influence kayak ownership and participation, empathetic user research determined where to focus the design. The most effective and expedient way of researching this was through surveys and interviews. It proved to be a challenge to conduct interviews with transforming kayak owners, as finding owners in this niche market was incredibly difficult. Instead, including open-ended questions on the kayak surveys captured emotive, expressive responses from owners. Digital surveys were an effective tool for distributing the survey to a range of people, including non-kayakers and different cross-sections of the kayaking population. This helped me to understand likely perceptions and learn from respondent's first hand personal kayaking experiences. On reflection a follow-up survey would have been useful further into the process once some of the issues were better understood.

Findings from more than 120 respondents helped to identify the kayak brands and models owned and used. These were reviewed later in regards to evaluating current market kayaks. The data helped quantify how much time was spent on different touch points of the kayak experience and the difficulties experienced with each model. It also helped to support my hypothesis through identifying the primary lifestyle factors to be time, portability and dwelling. The more qualitative data provided specific details around the experience to help me to design with empathy. Some of the data was superfluous to requirement and it was a challenge to identify trending data from 120 respondents and structure the information.

The second question which informed the designs explored exemplars in current market transforming kayaks. It looked at what was and wasn't working to address the lifestyle factors influencing the kayaking experience. This review was underpinned by data from The Kayaking Experience Survey (2014) which ascertained popular kayak models. These were mapped according to their system type, then further analysed in a range of categories and rated against lifestyle factors. Trends became especially apparent when looking at the setup and pack down process. All kayak systems had some level of assembly.

According to respondent data, the average set up time of transforming kayaks was approximately 30 minutes. This is a significant amount of time, and a major reason transforming kayaks are not the dominant choice of kayak. By integrating the design I have managed to reduce setup time to under a minute, making time not an issue for my transforming kayak designs. This means a lot more paddling time on the water and a better user experience.

Running parallel with the current model kayak review was a study of other transforming products undertaken to understand what worked and what could transfer to kayak design. The products studied included examples of different transforming systems and a much greater range of M.O.R.P.H. facilitators. This had the aim of making comparisons between kayaks and other transforming products, and looking for potential design applications in the design of new system solutions.

6.1.1 Evaluating the M.O.R.P.H. Framework

The M.O.R.P.H. Transformation Framework supported the process through different stages of inquiry to identify the lifestyle factors and categorise the current market to inform the design. In the context review the framework highlighted the issues with current kayak models. This helped to identify key trends and highlight opportunities for design alternatives. By categorising ideas using the heuristic 'Principles and Facilitators', the framework also categorised different solutions, with successful design solutions applied to each iteration. The M.O.R.P.H. framework was theoretical and had few case studies to evaluate, learn from, and apply to my process. This worked in my favour as I used the heuristics to review the current kayak market even though the framework was designed for ideation. The framework has sparked a number of associated studies from the University of Texas where it was first published. The studies add to the toolset, but these are all applied to the design phase. I believe further potential lies with using the framework as a research and evaluation tool.

The other key discovery from applying The M.O.R.P.H. framework was looking at the way deployment of transforming products is initiated and controlled. This study revealed the trigger as an ideal central point of deployment and discussed the different types of triggers and their effect on deployment. While no kayaks were identified to have a trigger, other products were observed to have at least some degree of trigger deployment. It was observed that the existence of a trigger had multiple benefits; not just in the speed of the deployment, but also in the efficiency of learning how to deploy a product. The designs in this study incorporated a trigger to enable a fast and easy setup.

The main question in this study is answered through the design outcomes. Can new transforming kayak designs overcome the barriers to participation? I believe they can.

I have addressed and incorporated potential solutions to the primary factors inhibiting kayak enjoyment into my designs. I believe that this collection of design elements make up a series of kayaks that have the potential to meet the needs of users better than current market kayaks. The translation of research created the design criteria. The possible design solutions are the innovations as detailed in Chapter 5: Designing the Kayaks.

Rather than describing each innovation, a series of diagrams will show the improvements that I have identified in transforming kayak design to remove barriers to participation. **Figure 68** highlights the design innovations, and lists them as they relate to the design and design criteria. The graphic corresponds to the design features provided within Chapter 5: Designing the Kayaks. To assist understanding of these design elements. **Figure 69** then takes each numbered innovation and applies it to the primary

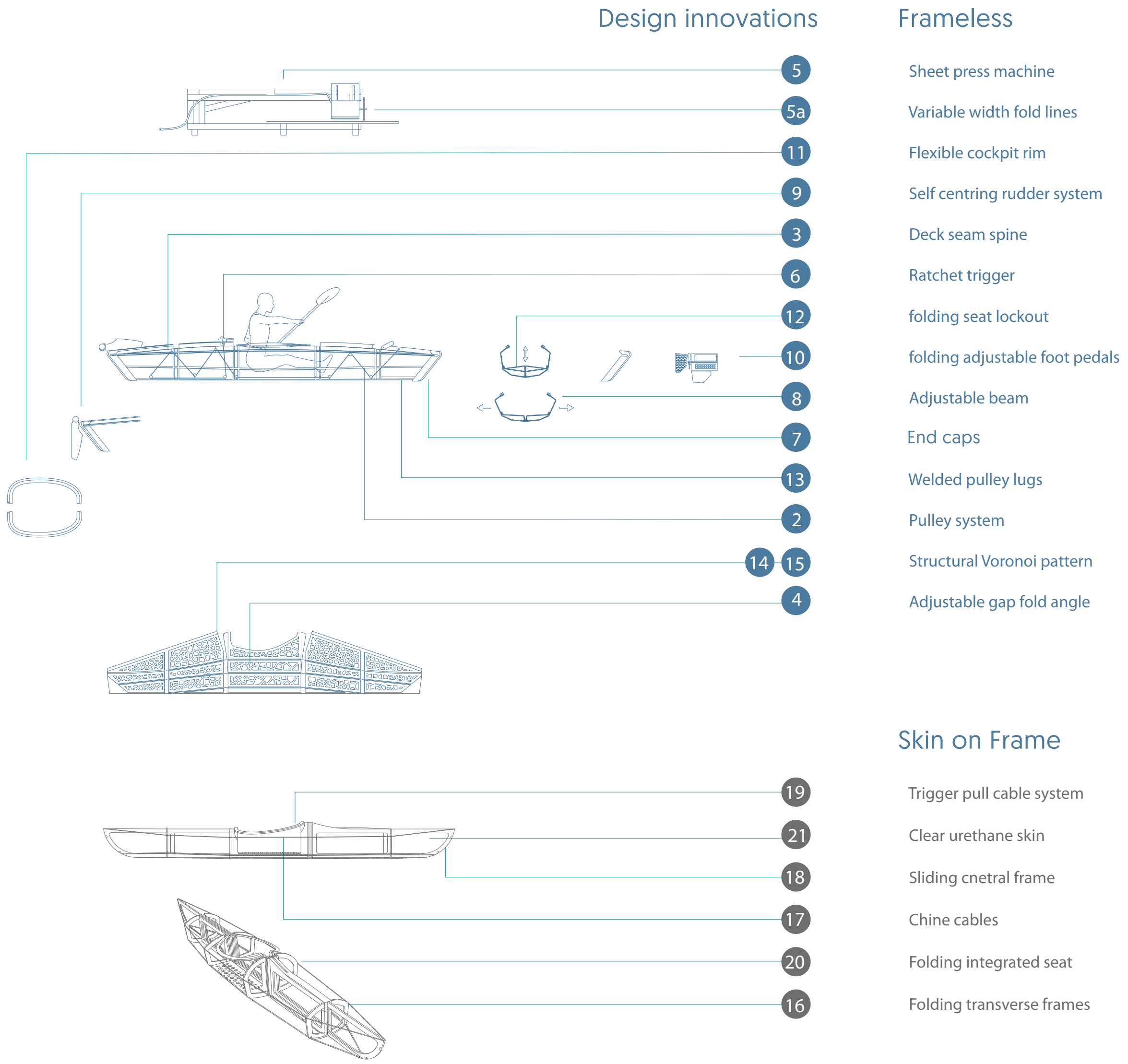


Figure 68. Numbered design innovations as they relate to the design criteria and design Chapters 5-6.

and secondary lifestyle factors the innovation helps overcome. It can be seen from this diagram how the innovations can help to overcome the barriers to kayaking, such as time and portability, by using fully integrated and trigger deployed systems.

With primary and secondary factors being interrelated, many share innovations to address these factors. For example innovation number 8 (beam adjustment) helps to solve issues affecting several secondary factors — stability, safety, and adaptability where the primary factor is performance. Being able to adjust

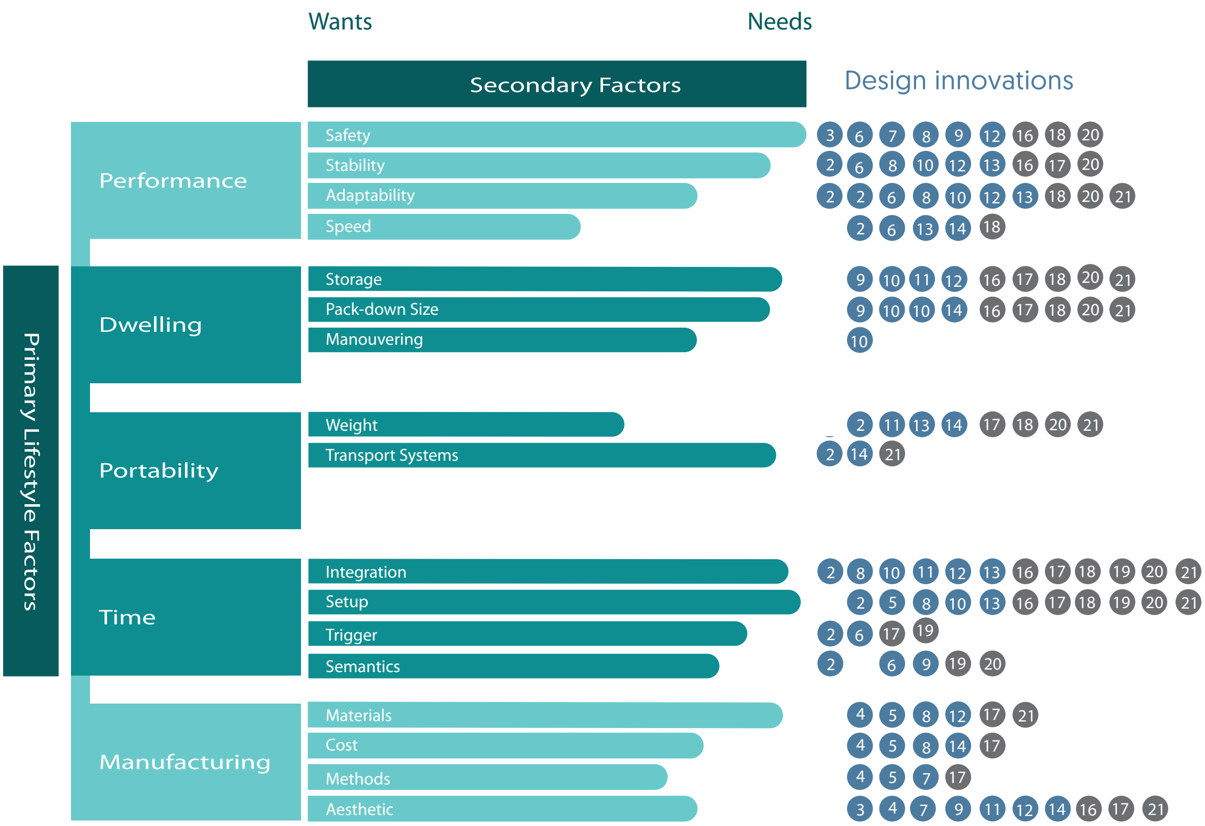
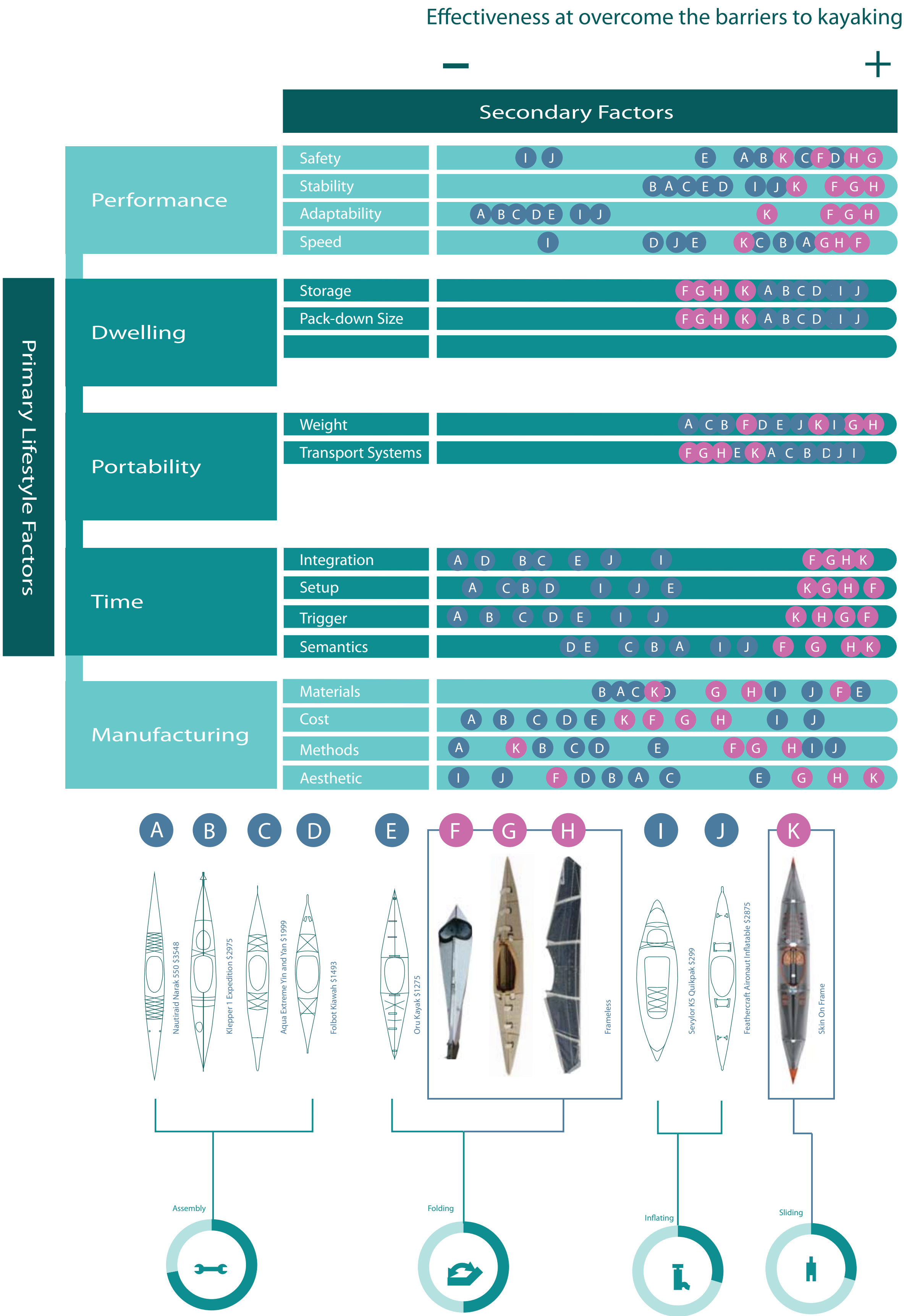


Figure 69. Design innovations as identified in Figure 68 applied to the primary and secondary lifestyle factors and physical factors.

the beam means the kayak can be adapted to be more stable for the conditions.

The final diagram of the study, **Figure 70**, evaluates the effectiveness of my designs compared to current market kayaks used as exemplars throughout this process. The diagram points to the resulting designs providing potential solutions to overcome the majority of factors inhibiting kayak participation.


Effectiveness at overcome the barriers to kayaking
–
+
Secondary Factors
Primary Lifestyle Factors
Performance
Safety
I J E A B K C F D H G
Stability
B A C E D I J K F G H
Adaptability
A B C D E I J K F G H
Speed
I D J E K C B A G H F
Dwelling
Storage
F G H K A B C D I J
Pack-down Size
F G H K A B C D I J
Portability
Weight
A C B F D E J K I G H
Transport Systems
F G H E K A C B D J I
Time
Integration
A D B C E J I F G H K
Setup
A C B D I J E K G H F
Trigger
A B C D E I J K H G F
Semantics
D E C B A I J F G H K
Manufacturing
Materials
B A C K D G H I J F E
Cost
A B C D E K F G H I J
Methods
A K B C D E F G H I J
Aesthetic
I J F D B A C E G H K
A B C D E F G H I J K
Nautiraid Narak 550 $3548
Klepper 1 Expedition $2975
Aqua Extreme Yin and Yan $1999
Folbot Kiawah $1493
Oru Kayak $1275
Frameless
Sevylor K5 Quikpak $299
Feathercraft Aironaut Inflatable $2875
Skin On Frame
Assembly
Folding
Inflating
Sliding

6.2 Trajectory, Potential and Final Recommendations

This study adds to the body of knowledge and collective works in the design of transforming objects. It also provides a case study for the application of the M.O.R.P.H. Transformation Framework in design. The resulting kayak designs present a case for further research and possibly development with the sliding skin on frame kayak design. Ultimately the best way to realise potential is from a greater market share of transforming kayaks, and happy kayakers who are able to overcome the barriers to kayaking through good design.

Research from this study provides a set of design ideas that could inform the design of other types of kayak development. The focus of this study was the sit-in, rather than the sit-on, kayak. There is potential for further research into sit-on kayaks which are growing in popularity. Another market that could be further explored is transforming race kayaks with the ability to adjust for the user’s peak performance in different conditions. Also considered is the possibility of an easily stored emergency kayak for areas prone to natural disasters such as flooding.

I look forward to a future where transformation and integration has enabled me to once again climb into my kayak and explore the inlets and city beaches. It is then that I will claim back those Zen moments, the previous lifestyle barriers no longer in my way.

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8.0 List of Figures

All figures unless cited are the work off Jason Mitchell, author of this Exegesis. All figures used in this Exegesis are Creative Commons licensed and are public domain.

9.0 Appendices

9.1 Massey low risk notification

Massey University
Te Kunenga ki Pūrehuroa

Research Ethics

NOTIFICATION OF LOW RISK RESEARCH/EVALUATION INVOLVING HUMAN PARTICIPANTS

(All notifications are to be typed)
(Do not modify the content or formatting of this document in any way)

SECTION A:

1. **Project Title** Rethinking Design In The Marine Industry

   Projected start date for data collection 1/6/2013 **Projected end date** 1/9/2013

   (Low risk notifications will not be processed if recruitment and/or data collection has already begun.)

2. **Applicant Details** *(Select the appropriate box and complete details)*

ACADEMIC STAFF NOTIFICATION

Full Name of Staff Applicant/s

School/Department/Institute

Region *(mark one only)* **Albany** ☐ **Palmerston North** ☐ **Wellington** ☐

Telephone **Email Address**

STUDENT NOTIFICATION

Full Name of Student Applicant Jason Kirk Mitchell

Postal Address 18 Carlton Street, Melrose, Wellington

Telephone 0211127197 **Email Address** j.k.mitchell1@massey.ac.nz

Employer (if applicable) **Massey University**

Full Name of Supervisor(s) Anthony Pelosi, Stuart Foster

School/Department/Institute SoD (School of Design)

Region *(mark one only)* **Albany** ☐ **Palmerston North** ☐ **Wellington** [*]

Telephone 0211127197 **Email Address** j.k.mitchell1@massey.ac.nz

GENERAL STAFF NOTIFICATION

Full Name of Applicant

Section

Region *(mark one only)* **Albany** ☐ **Palmerston North** ☐ **Wellington** ☐

Telephone **Email Address**

Full Name of Line Manager

Section

Telephone **Email Address**

9.2 M.O.R.P.H. Framework and Other Studies

The following studies address the M.O.R.P.H. Transformation Framework and associated studies that add to and build on the body of knowledge.

1. This study essentially covers the 'indicators' of transformation. This relates to when an object should transform and sets about a method for finding out the value an object might have through transformation (Camburn et al., 2010)

Camburn, B. A., Guillemette, J., Crawford, R. H., Wood, K. L., Jensen, D. J., & Wood, J. J. (2010). When to transform? Development of indicators for design context evaluation. In *ASME 2010 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (pp. 249–266). American Society of Mechanical Engineers. Retrieved from http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1612326

2. An empirical study of 190 transforming products understanding which facilitators are most popular and how they work together. (J. M. Weaver, Wood, & Jensen, 2008)

Singh, V., Skiles, S. M., Krager, J. E., Wood, K. L., Jensen, D., & Sierakowski, R. (2009). Innovations in design through transformation: A fundamental study of transformation principles. *Journal of Mechanical Design*, *131*(8), 081010.

3. This builds on transformation design theory by adding a 'meta-analogical framework'. It provides methods in which transformation can be applied using the 'principles and facili-

tators' discussed in other works. (J. Weaver, Wood, Crawford, & Jensen, 2010)

Weaver, J., Wood, K., Crawford, R., & Jensen, D. (2010). Transformation design theory: A meta-analogical framework. *Journal of Computing and Information Science in Engineering*, *10*(3), 031012.

4. This chapter discusses a set of tools for ideation in transforming products. (Singh, Walther, Wood, & Jensen, 2009)

Singh, V., Walther, B., Wood, K., & Jensen, D. (2009). INNOVATION THROUGH tRaNsFoRmAtIoNaL DESIGN. *Oxford University Press*. Retrieved from http://www.sutd.edu.sg/cmsresource/idc/books/2009_Chapter9_Innovation_through_Transformational_Design.pdf

5. This paper combines and inductive and deductive approach for designing transforming products using analogies from a wide variety of natural and material possibilities. The process aims to use these analogies to be more divergent in ideation. (Singh, Skiles, et al., 2009)

Singh, V., Walther, B., Krager, J., Putnam, N., Koraishy, B., Wood, K. L., & Jensen, D. (2007). Design for transformation: Theory, method and application. In *ASME 2007 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (pp. 447–459). American Society of Mechanical Engineers. Retrieved from http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1604220

9.3 Kayak Experience Survey

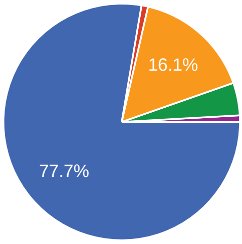
This survey was conducted in 2013 as a means to understanding kayak participation and user experiences with kayaks. Some comments have been cut to reduce page count.

112 responses

View all responses   Publish analytics

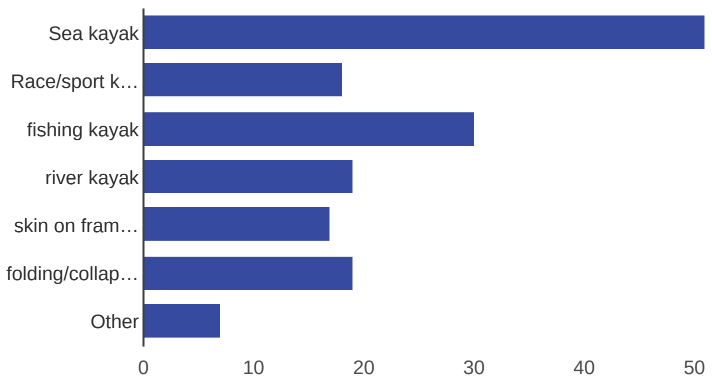
Summary

1. What answer best fits your level of kayak interaction and ownership?



I own/have previously owned a kayak	**87**	77.7%
I have access to a kayak from a friend/club	**1**	0.9%
I do not own a kayak but have dabbled in it a few times.	**18**	16.1%
I have never paddled a kayak, but would like to try (go to Q3)	**5**	4.5%
I have never paddled a kayak and have no interest in doing so	**1**	0.9%

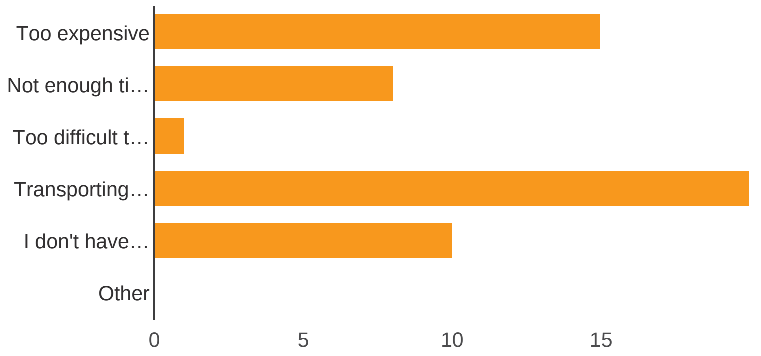
2. Which of the following types of kayak do you own/use?



Sea kayak	**51**	54.3%
Race/sport kayak	**18**	19.1%
fishing kayak	**30**	31.9%
river kayak	**19**	20.2%
skin on frame kayak	**17**	18.1%

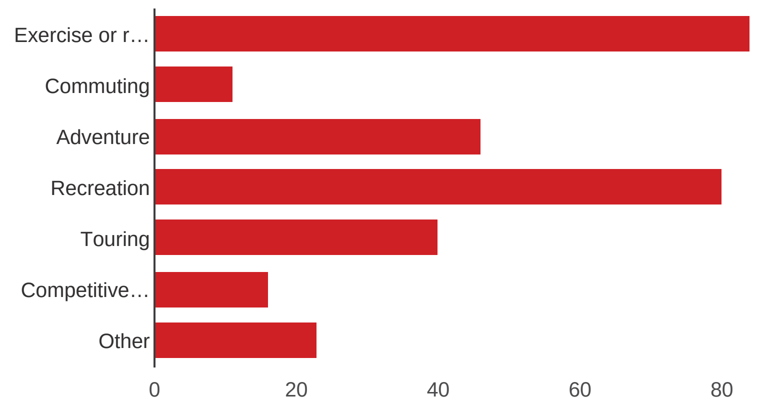
folding/collapsible kayak	**19**	20.2%
Other	**7**	7.4%

3. If you do not own a kayak but would like to, what do you consider are the barrier/s to ownership?



Too expensive	**15**	53.6%
Not enough time	**8**	28.6%
Too difficult to learn	**1**	3.6%
Transporting a kayak is too difficult	**20**	71.4%
I don't have anywhere to store it	**10**	35.7%
Other	**0**	0%

4. What do you use your kayak for? If you have never owned/used a kayak but would like to, what would you use it for?



Exercise or relaxation	**84**	75%
Commuting	**11**	9.8%
Adventure	**46**	41.1%
Recreation	**80**	71.4%
Touring	**40**	35.7%

Competitive sport	**16**	14.3%
Other	**23**	20.5%

4a. Which of the above, or other (please state) would you like to be able to do but current circumstances are a barrier? Can you specify the barrier?

longer time to paddle after work, its dark by the time I pack down for most of the year and easy to lose parts.

no

None, tramping with a folding kayak is possible, but setting up takes way too long.

Commuting, but I have nowhere for storage at work.

All of them require a lightweight boat that I can single hand onto the roof of my car. also I am 6'3" and 225 lbs so I need a large boat.

Touring, hard to do with a heavy kayak.

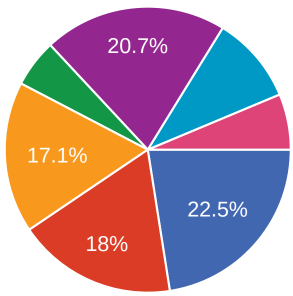
All of them, I live in an apartment

I have a folding kayak, but no car. It's difficult sometimes to reach the put-in place

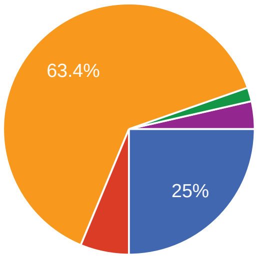
pertinent issue. Folders tend to flex which makes them great in weather, but generally a little slower than hard-shelled boats

no garage. hard to get it to the beach

5. On average how often do you go kayaking?



A few times a month	**25**	22.5%
Once a week	**20**	18%
A few time a week	**19**	17.1%
Every Day	**6**	5.4%
As often as i can	**23**	20.7%
Never	**11**	9.9%
Other	**7**	6.3%



Apartment	**28**	25%
Townhouse	**7**	6.3%
House	**71**	63.4%
Dorm/shared facility	**2**	1.8%
Other	**4**	3.6%

7. If you own a kayak where do you store it ? (If multiple locations i.e. At home in the garage on hoists and at work in the bike lockup).

Garage

In slings under my deck.

We have amny kayaks so if there is a place to store one we already have one there

Rack outside house

house

Garage and house

Under the stairs

carport on a trailer

barn

boat shed

In the garage

backyard

home storage shed

garage & outside I have 4. one is and antique folding yak

at home, in a closet

Outside

Racks I have installed at home.

Folding ones in my flat, others at a marina or in storage

garage ceiling and basement

outside

At home

home in the mancave

At home in the garage

Sea kayak on ahoist, folders in their bags in closets.

Inside garage

8. If you do not own a kayak where would you likely store it if you did (be specific)?

My parent house, no room in my dorm area

nowhere really. in the hall?

Garage

in backyard

Probably on my wall

under stairs

in the garage

I really don't know it's too big for my apartment.

under the house

In my bedroom

In the lounge or the ceiling

at my parents

At my sons house

In shared lockup

garage

In my cabin (ship)

dont know

9. What difficulties do you have with storing your kayak? If you do not own a kayak what are the perceived difficulties?

none if I lived in a small dwelling with space as a issue or traveled alot and far from home a folding kayak would be an option. I currently own a antique folding kayak. Tyne is the brand. its very inadequate for my needs. I do touring and the tyne is only 14 foot

storage in my apartment isn't a problem

I have too many kayaks, 10 at the moment. A bit hard to store.

Other than the one fold up I built they take up too much space or if hung from the ceiling are a pain to get down.

It's heavy to take it down: it's hanging on the ceiling

No difficulties, it hangs in cradles above the car in the carport, and I just drop it onto / lift it off the roofrack

it would be heavy and I don;'t have anywhere to store it.

Too much stuff in !y garage.

No difficulties. I have room enough for several kayaks

Not enough covered room

Major difficulty is security.

It is awkward to hoist up from the roof.

It takes up the small amount of room we have outside.

takes up alot of floor space in the garage

won't fit in my apartment (hardshell)

They are very long

it wouldnt fit very well under the house

Length is 4.8m, so takes up a lot of space

Its long and difficult to manouver

10. How do you transport your kayak? Be specific, i.e. if by car is it tied to the roof on racks, or multiple/varying transportation systems? If you do not own a kayak how would you likely transport it?

Would like Public transport, boot of car, ship. Currently roof rack

I would likely put it on the car roof, but don't have racks

Roof racks.

I would likely transport it on a trolley as I'm close to the water

Roof racks

I have a folding kayak that I designed myself. It fits in a suitcase and weighs 15 kg including weight of case.

on car roof rack or trailer

Car/Roof Rack

I tie it to racks on my truck.

folding kayaks go in backpacks for the motorbike or trolley bags for trains and ferries. The sailing canoes are tied to the roof on car roof racks

in the boot for the folding, on the roof for the solid kayak.

We have a trailer that can transport 4 at one time.

Custom trailer

Roof racks with Yakima Jaylow cradles

I would put it on the roof somehow

Roof rack on car. Folding j rack.

On the car roof on kayak racks

85% of the time I use roof racks transporting up to two kayaks, 15% I use a trailer transporting multiple kayaks

car roof rack

Home made truck rack

Roof of my vehicle on either my factory or aftermarket racks.

As checked luggage, Roof Rack

On top of my truck.

In J-cradles on a roofrack

On my car, I have racks

back of station wagon

Roof rack on car

11. What difficulties do you have with transporting your kayak? If you do not own a kayak what are the perceived difficulties?

Would like to be able to transport multiple kayaks.

The weight of the kayak and having to lift it up and on to the car roof.

No difficulties but extra cautious to reluctant with strong cross winds.

They are big and heavy don't know how I would get it in and out of my apartment.

Surface area of it when windy. Can new difficult getting on the roof

Can only take 3 at once

Weight - over 30kg. At the end of a big day, this is quite a beast to handle onto the top of the car.

Loading on & off roof. Having to wash down entire car after a trip in the salt

Weight of the kayak and height of the car can make loading difficult.

Salt water is bad for the vehicle, rust is a big problem.

Owning a high vehicle, a heavy Kayak can be tricky to lift onto the roof racks. Can be hard in strong winds also.

Putting kayak up by myself on the roof of car

It's still a bit bulky and heavy to transport by hand

too much over hang

My SUV is so tall that sometimes I have trouble tying them down.

getting it on to the roof on your own

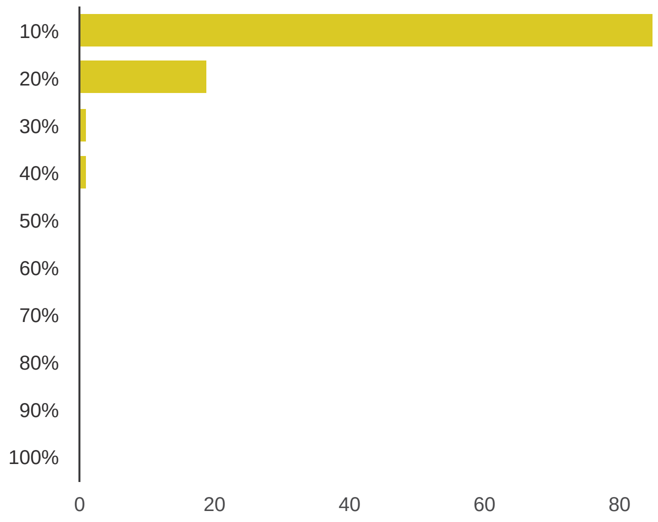
was difficult to load until I designed rollers to assist loading/unloading on trailer, now I can do this solo

Loading and unloading from a tall vehicle is challenging.

No difficulties

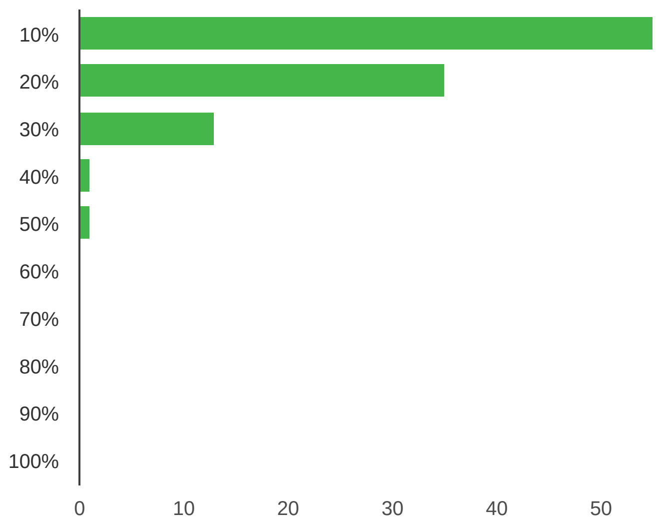
Length and weight

It is heavy to lift off the roofrack to the ground on my own



40%	**1**	0.9%
50%	**0**	0%
60%	**0**	0%
70%	**0**	0%
80%	**0**	0%
90%	**0**	0%
100%	**0**	0%

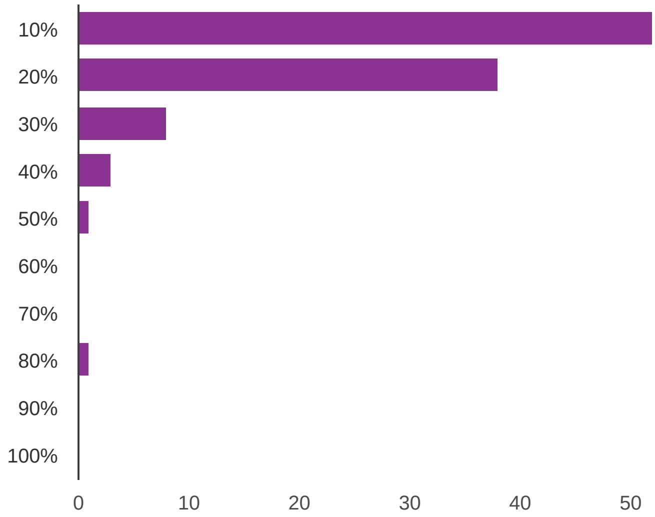
In transit [12. On average what percentage of time do you spend within associated kayaking activities?]



10%	**55**	52.4%
20%	**35**	33.3%

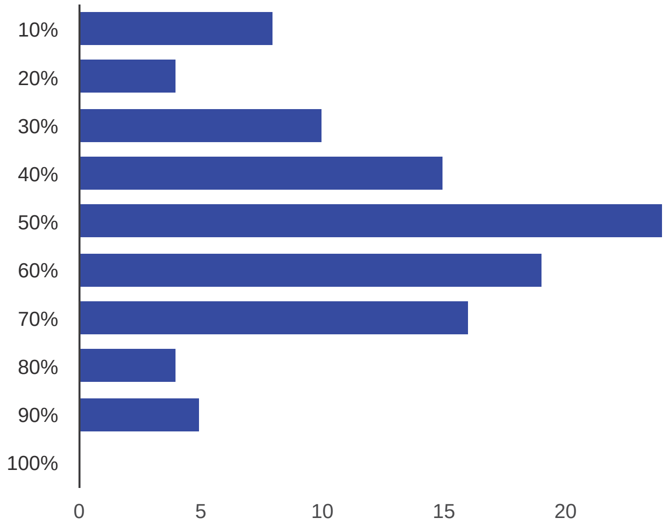
30%	**13**	12.4%
40%	**1**	1%
50%	**1**	1%
60%	**0**	0%
70%	**0**	0%
80%	**0**	0%
90%	**0**	0%
100%	**0**	0%

Setup, packdown and change [12. On average what percentage of time do you spend within associated kayaking activities?]



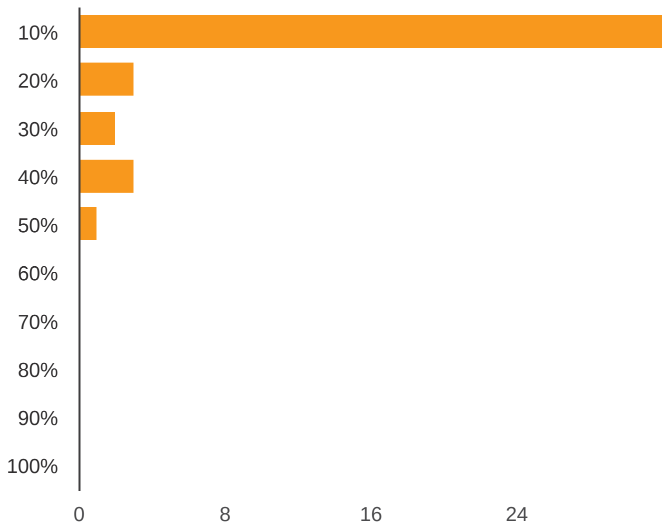
10%	**52**	50.5%
20%	**38**	36.9%
30%	**8**	7.8%
40%	**3**	2.9%
50%	**1**	1%
60%	**0**	0%
70%	**0**	0%
80%	**1**	1%
90%	**0**	0%
100%	**0**	0%

Paddling [12. On average what percentage of time do you spend within associated kayaking activities?]



[illegible]	[illegible]	[illegible]
20%	**4**	3.8%
30%	**10**	9.5%
40%	**15**	14.3%
50%	**24**	22.9%
60%	**19**	18.1%
70%	**16**	15.2%
80%	**4**	3.8%
90%	**5**	4.8%
100%	**0**	0%

Other [12. On average what percentage of time do you spend within associated kayaking activities?]



10%	**32**	78%
20%	**3**	7.3%
30%	**2**	4.9%
40%	**3**	7.3%
50%	**1**	2.4%
60%	**0**	0%
70%	**0**	0%
80%	**0**	0%
90%	**0**	0%
100%	**0**	0%

12a. Which of the associated kayaking activities in question 12 (if other, please specify) do you find most frustrating and why?

The honest answer is the travel time (I live in Matamata - significant travel is required for most of my marine paddling). I use the setup and packdown procedures to also maintenance and safety check my craft. This is critical as much of the paddling I do is classed as "adventurous".

Getting ready for transport. Irritating to collect all the equipment.

Setup packdown & change

securing the kayak to the trailer is a real pain, my concern for safety has me using 6 separate tie downs and this can take 5-10 minutes on setup and takedown.

Setup and pack down.

I can do loading/unloading very quickly, maybe 10 min each. I wish some of my favorite paddling spots were a bit closer.

Always a pain having to drive long distances.

setup. getting all the gear together, getting safety equipment on etc.. I'd rather just toss the boat in the water and go.

Transit would be the most frustrating.

When travel time exceeds kayak time, I consider it wasteful

Getting changed in the cold

set up and pack down seems like dead time and packdown you are often abit tired

Transport

Packing up afterwards

Setup is the worst it takes more time for that than i get to paddle, but i love the convenience of it.

Setup for the folding kayak.

I live 8 miles from the closest put in so I spend too much time traveling.

Flushing with fresh water the equipment,cleaning and drying the kayaks and equipment

set up and pack down

forward, but lots of components to put together.

Answering stupid, unscientific surveys

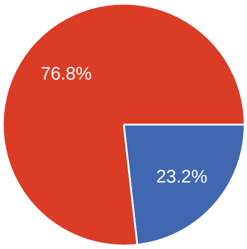
it takes about 5 minutes to load and 5 to unload

Set up, pack down

Packing up and unpacking. I feel it could be easier

The collapsible kayak

13. Do you own or use a collapsible/folding kayak



Yes	**26**	23.2%
No (go to Q13b)	**86**	76.8%

13a. What brand and model is it?

Feathercraft

Aqua Extreme - Yin and Yan

I own more than 1

Long Haul & Klepper

I don't know the brand... Inflatable

folbot -citibot & kiawah

Pakboat Quest 135, Fujita Alpina a1 400, Nautiraid K1, Incept k40, had Nautirqid Narak, original AirFusion by Advanced Elements

tyne

I have six: Klepper AE II, Klepper T67, Nautiraid Miniraid, Pionier 450S, Kette Sporteiner 54, Hartung Slalom.

Homemade

Used to own an inflatable Sevylor

klepper

Yost Sonnet

Folbot not sure on model

Kepplar

Klepper

Folbot

Feathercraft Big Kahuna

Oru

Folboat

2 kayaks: a Klepper Aerius Expedition I SL490 and a Folbot Greenland II

Tom Yost design, built it myself

Viking pro fish 400

13b. What were your main reasons for purchasing or using a collapsible/folding kayak? If you do not own, or have never used one would it appeal to you, and why?

I liked the transportability of it. its a cool gimmick.

Ease of transport.

NO, to get the join strong and water tight, it would be heavy.

I like the idea that it could fold up to the size of a set of golf clubs.

versatility in storage, suitability for expedition

One way journeys possible, ferry air train and motorbike portage possible, the soft skin is more forgiving in rough water, they are short and fairly narrow mostly so easy to paddle and surf well. They are light so easy to carry to and from the water.

Yes it would appeal as long as setup is easy/ quick and it handles well.

At this point it does not interest me.

A nice folder would be convenient.

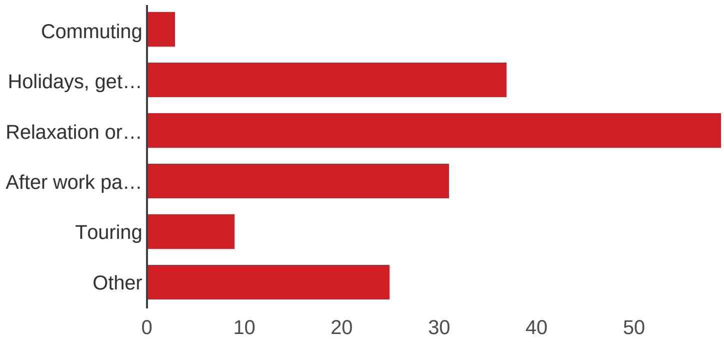
Collapsible kayaks may be easier to store and transport, but they pay a huge performance penalty. Inflatable kayaks can be made into complex shapes but lack rigidity and deform on the water. Foldable type kayaks can hold shape but that shape is necessarily simple and inefficient on the water. The bottom line is that they are much heavier and much slower than what I currently paddle. Set up and tear down times are also problematic.

Not sure that it would appeal to me. I would have to test paddle one to find out.

No, more moving parts, more things to go wrong. More weight, more flex...

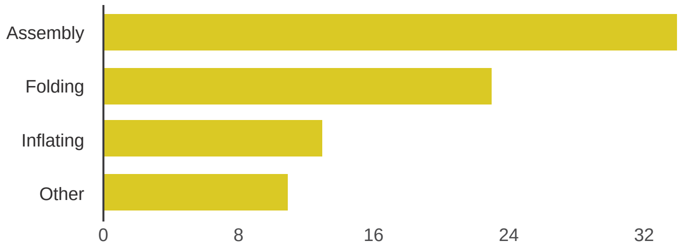
yes would be able to manage it on my own

It would NOT appeal to me because performance on the water trumps all other considerations, and I believe that excellent speed, stability, and maneuverability can only be had with a rigid one-piece kayak. A great deal of thought goes into designing the hull of a performance kayak. Knowledgeable kayakers are well aware of the design characteristics. They study them very carefully: width, length, rocker, chine, shape of the bottom, cockpit size, flare, etc. I don't believe that a collapsible kayak can come close to the design characteristics of a well-designed rigid kayak. An experienced kayak figures out how to deal with the logistics of preparing, loading, and storing a kayak. It takes me 10 minutes to get my kayak out of the garage, on the car,



Commuting	**3**	3.3%
Holidays, getting away	**37**	41.1%
Relaxation or exercise	**59**	65.6%
After work paddle	**31**	34.4%
Touring	**9**	10%
Other	**25**	27.8%

13c. When setting up the kayak what type of preparation is required?



Assembly	**34**	73.9%
Folding	**23**	50%
Inflating	**13**	28.3%
Other	**11**	23.9%

Cost [14. What are the advantages and disadvantages of a collapsible/folding kayak over a traditional kayak? If you do not own, or have never used one what are the or perceived advantages/disadvantages?]

Advantage	**27**	24.1%
Disadvantage	**48**	42.9%
Both are similar	**37**	33%

Weight [14. What are the advantages and disadvantages of a collapsible/folding kayak over a traditional kayak? If you do not own, or have never used one what are the or perceived advantages/disadvantages?]

Advantage	**46**	41.1%
Disadvantage	**38**	33.9%
Both are similar	**28**	25%

Setup time [14. What are the advantages and disadvantages of a collapsible/folding kayak over a traditional kayak? If you do not own, or have never used one what are the or perceived advantages/disadvantages?]

Advantage	**8**	7.1%
Disadvantage	**97**	86.6%
Both are similar	**7**	6.3%

Ease of setup [14. What are the advantages and disadvantages of a collapsible/folding kayak over a traditional kayak? If you do not own, or have never used one what are the or perceived advantages/disadvantages?]

Transporting [14. What are the advantages and disadvantages of a collapsible/folding kayak over a traditional kayak? If you do not own, or have never used one what are the or perceived advantages/disadvantages?]

Advantage	**100**	89.3%
Disadvantage	**5**	4.5%
Both are similar	**7**	6.3%

Storing [14. What are the advantages and disadvantages of a collapsible/folding kayak over a traditional kayak? If you do not own, or have never used one what are the or perceived advantages/disadvantages?]

Advantage	**105**	93.8%
Disadvantage	**2**	1.8%
Both are similar	**5**	4.5%

Performance [14. What are the advantages and disadvantages of a collapsible/folding kayak over a traditional kayak? If you do not own, or have never used one what are the or perceived advantages/disadvantages?]

Disadvantage	**63**	56.3%
Both are similar	**30**	26.8%

Aesthetic [14. What are the advantages and disadvantages of a collapsible/folding kayak over a traditional kayak? If you do not own, or have never used one what are the or perceived advantages/disadvantages?]

Advantage	**15**	13.4%
Disadvantage	**59**	52.7%
Both are similar	**38**	33.9%

15. How long does it take (minutes) to setup/packdown the collapsible/folding kayak?

Total setup time ~15 minutes

35

30-40 minutes

40

15 minutes

30 minutes for the basic boat

22

25

30

How many times do I have to say I don't have and dont want one?

15

45 min total

20 minutes

40 to 50 minutes

30-60

35-40

A few hours

30 mins

30 minutes

about 40 minutes, but got faster at it over time.

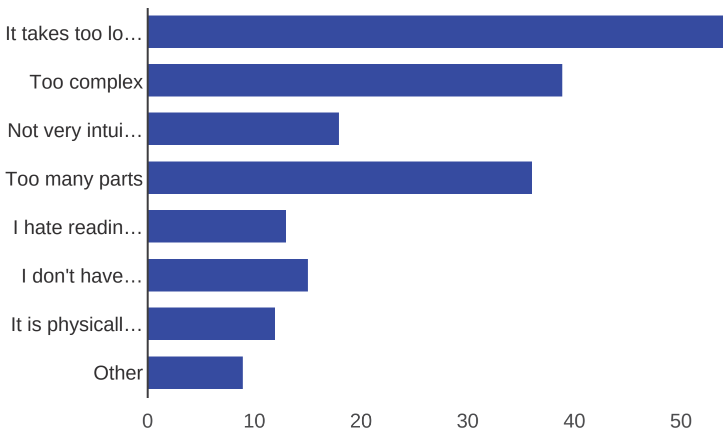
15 min

less than 1 minute

60

30 minutes for both

15a. What are the most difficult or frustrating issues when setting up and packing down a collapsible/folding kayak. If you have never been through the process what do you percieve to be the most frustrating?



It takes too long, i don't have the time	**54**	58.7%
Too complex	**39**	42.4%
Not very intuitive	**18**	19.6%
Too many parts	**36**	39.1%
I hate reading instructions	**13**	14.1%
I don't have any difficulties	**15**	16.3%
It is physically difficult to setup	**12**	13%
Other	**9**	9.8%

16. If you could change anything in the design of the collapsible/folding kayak what would it be.

Simplicity of instructions

Pay more attention to hull shape, just like all the better sea kayak makers do. Folding kayak makers did just that many years ago when folders were used competitively.

Design it so i could take it on my bike

reduce number of assembly steps, reduce overall weight (I have the carbon-framed klepper and that helps, but lighter is always better)

own a frameless kayak that does not look like an inflatable kayak

cost

Just make it inflatable. Fill it with air and go. When done , deflate, fold it up stuff it it's bag and go home.

Durability along with lightweight. fast assembly.

A collapsible kayak may be useful for a person with limited storage and/or transport capability. Other than that, from a performance perspective, they will ALWAYS be inferior to a rigid kayak. They will be heavier, slower, more expensive and take longer to get on the water.

The skin is hard to stretch over the frame, physically difficult to put it all together if i rush it and it is not perfect. I would make it easier and failsafe to put together.

Make it easier to setup and much quicker.

I think I would feel less secure in a collapsible kayak.

Would not

lighter

Create a sit-on-top style suited to marine fishing applications and this is the most significant part of my kayaking on an annual basis.

Lighter Weight

Make it cheaper, less parts maybe, and really easy to carry while walking.

Put wheels on it like a trundler bag.

weight. It needs to be super light to be useful for me.

16b. Would these changes enable you to kayak more often, or help remove barriers to kayaking?

no

not more often but would make it easier and probably have longer length of time on the water.

it would allow me to kayak more remote places

Yes, we need faster and easier to paddle folders.

maybe

yes.

possibly

Definately

neutral

does not apply

More access to launch sites.

no, it would just increase enjoyment

probably

9.4 Personas

The personas were created as a means of better identifying the needs of people involved in kayaking.

Vincent

The Traditionalist

+ ADD

AGE	54 (55.8% of respondents)
OCCUPATION	Sales
STATUS	Married, adult children
DWELLING	Suburban house and bach
USE	3 - 4 times/week
ARCHETYPE	The Traditionalist
KAYAK OWNER	Hardshell Sea kayak and Multisport

Curious · Inventive · Explorative

+ ADD

" It gets harder to wield a big kayak around and get it to where I want it."

Lifestyle Factors

+ ADD

- Price Conscious
- Location Dependant
- Transport Dependant
- Time Dependant
- Physical Aptitude

Goals

- Would like to compete in a kayak endurance event.
- Wants a work/life balance, bring on retirement.
- Wants to go on a long touring trip and take a kayak.

Frustrations

- Getting the kayak on and off the roof of the SUV.
- Not enough hours in the day to fit in the fun stuff and train for an event.
- Too many toys in the garage, my older kayak gets left outside.

Description

The traditionalist is interested in kayaking as a hobbyist and enthusiast. A later career kayaker encompassing the largest proportion of interview and survey respondents at 55.8%. They are usually highly experienced kayakers and have the necessary means to overcome some of the frustrations around the kayaking experience i.e. they own a vehicle, and a house. Their greatest frustrations are not having enough time to kayak, mostly due to more senior job roles. Due to the time it takes to get ready for kayaking it is hard to get home from the daily commute during the week to kayak, "it would be nice being closer to the water". Their motivation for kayaking ranges from health and fitness to adventure.

They are often wary of new technology, tending to focus on quality and long term product success before investing in new options. They invest time in keeping up with technology, but as consumers generally stick with what they know. Smartphones are seen as overly complex and if the technology is not intuitive then interaction is frustrating.

Transforming kayaks are not normally considered by the traditionalist, primarily due to the time it takes to get the kayak setup and in the water (38 minutes average from participant survey). This is despite the thought of being able to keep the kayak in the car for a quick paddle after work, without the worry of it getting stolen off the roof during the day. They don't mind spending money on quality, but quality transforming kayaks are a significantly higher investment than a hard shell. Being able to take a kayak on holiday easily and train after work would really help build towards those personal kayaking goals.

Kayak Motivation

+ ADD

- Recreation — Competition
- Performance — Cost
- Methodical — Intuitive

Technical Aptitude

+ ADD

- Digital technologies
- Construction/Assembly

Brands

+ ADD

Brands the traditionalist associates with.

Anton & Alice

The Lifestyle Focused

AGE	36 (1.2% of respondents)
OCCUPATION	IT specialists
STATUS	Married, no children
DWELLING	Boat, and city apartment
USE	1 - 2 x day
ARCHETYPE	The allrounders
KAYAK OWNER	Hard-shell and Folding

Nature lover

Carefree

Explorative

" It's all about speed, their is no substitute for seat time"

Lifestyle Factors

Price Conscious

Location Dependant

Transport Dependant

Time Dependant

Physical Aptitude

Goals

- Would like to explore more of her local area by kayak.
- Wants to increase upper body strength for her job.
- Wants more adventures camping and kayaking with friends.
- Commute to my practice on the other side of the harbour.

Frustrations

- "I'm not patient, it takes too long to get my gear together".
- Would like a higher performance kayak, but can't fit it in the apartment.
- Would like a mid range kayak, but folding kayaks are so expensive?
- "I keep losing parts, and sometimes its difficult to fit the seat if i don't get the pressure just right".

Description

The pragmatist invests in kayaking for multiple reason; as a tool for transport, carrying gear, commuting and exploring. They generally live near, or on, a body of water. They are often boat owners, sometimes as their main source of transport, and as their primary living space. They often think of kayaks as pragmatic equipment. Motivated by a flexible lifestyle where trips are well planned and the right equipment is important. They often commute short haul and use a kayak as a tender.

Flexibility is a key motivator, a kayak that can adapt to the situation and task at hand. They are adept at tight storage, and are always looking for better solutions, sometimes Frustrated when attempting to store a hardshell kayak aboard the boat. They express difficulties with existing transforming kayaks when assembling on a moving deck and in a tight space. Losing parts into the water is an anxiety they do not need.

The kayak as a tool is an investment that is carefully considered, often wanting the best of what both types of kayaks have to offer they invest in both, using them for the best suited task at hand.

Performance on the water is second to safety and stability, cost is a driver in the purchasing decision, depending on whether the bach and boat are primary dwellings. Mostly doing their own maintenance they have developed a reasonable practical understanding of construction, but they would rather spend time on enjoying their major assets, than assembling a kayak.

Kayak Motivation

Recreation — Practicle

Performance — Cost

Methodical — intuitive

Technical Aptitude

Digital technologies

Construction/Assembly

Brands Preference

(A collection or list of the user's favorite brands. You can download logos from www.brandsoftheworld.com)

FAKE CROW

Simone

The Explorer

AGE 28 (21.2% of respondents)
OCCUPATION Physiotherapist
STATUS Single, no children
DWELLING Apartment
USE 1 - 2 times/week
ARCHETYPE The Explorer
KAYAK OWNER Inflatable and assembly

Nature lover
Carefree
Explorative

" This is my escape from a busy life, It's my zen moment, I wish a folding kayak would help, rather than hinder this experience"

Lifestyle Factors

Price Conscious
Location Dependant
Transport Dependant
Time Dependant
Physical Aptitude

Goals

- Would like to explore more of her local area by kayak.
- Wants to increase upper body strength for her job.
- Wants more adventures camping and kayaking with friends.
- Commute to my practice on the other side of the harbour.

Frustrations

- "I'm not patient, it takes too long to get my gear together".
- Would like a higher performance kayak, but can't fit it in the apartment.
- Would like a mid range kayak, but folding kayaks are so expensive?
- "I keep losing parts, and sometimes its difficult to fit the seat if i don't get the pressure just right".

Description

The explorer is interested in kayaking as a means to explore nature and escape from a busy life, and the stresses of city living. They rarely own traditional hardshell kayaks, limited by urban apartment living, and lack of a vehicle to transport equipment. Busy professional and social lives mean it is difficult to get out and explore as often as they would like, spur of the moment adventures and group paddles is often the best way to get out into nature.

Their greatest frustrations is how long it takes to get the kayak ready, and the complexity of assembly.

They embrace new technology as long as it fulfills it's promise and is an enjoyable experience. They are quite methodical and require step by step instructions when they are assembling a kayak, they often find instructions are open to interpretation and find it very frustrating. They ideally want the simplicity and performance of a hard shell kayak in a transforming kayak.

Performance is second to cost, the explorer isn't after the fastest kayak, as long as it is robust, stable and can pack down small enough to carry on public transport. Ideally they would like a higher end kayak, but they are a large investment for someone in a relatively early career. They are concerned with all the parts required for assembly going missing if they are going on a trip.

Kayak Motivation

Recreation — Competition
Performance — Cost
Methodical — intuitive

Technical Aptitude

Digital technologies
Construction/Assembly

Brands

(A collection or list of the user's favorite brands. You can download logos from www.brandsoftheworld.com)

9.5 Manufacturing Suggestions

This is a basic overview of some of the proposed methods of fabrication and materials, but is not a final recommendation as design would require significant development before this takes place.

The holistic process of design not only considers the needs of the user, but also the fabricator and fabrication methods. This is known as concurrent engineering.

> "Concurrent Engineering is the practice of concurrently developing products and their manufacturing processes. If existing processes are to be utilized, then the product must be designed for these processes. If new processes are to be utilized, then the product and the process must be developed concurrently"(Anderson, 2014).

While this study is exploratory and does not follow development to the level of manufacturing, the materials and methods of fabrication still need to be understood even if only suggestive of how fabrication may be achieved.
The polypropylene kayak is fabricated from existing sheet materials, off the shelf components, and uses digital fabrication tools. This has a significant impact on the setup costs of component tooling and the machines that are needed to fabricate parts. Minimising materials and the way they are fabricated can also reduce manufacturing costs relative to the number of components being manufactured. Off the shelf fabrication of the polypropylene kayak could enable low cost start-up for fabricators and allow for mass customisation through the combination of existing materials and digital fabrication.

The skin on frame design could also be fabricated using a variety of material and manufacturing methods. For off the shelf fabrication the frame could be welded Marine/aircraft 6061-T6 aluminium/magnesium extrusion in an appropriate dimension with wall thickness to be determined through further testing. The aluminium could be anodised for a harder external coating and better resistance to oxidising and corrosion. Composites are another option for frame materials, there are a number of methods and materials, with a likely candidate being a combined carbon Kevlar multi-directional weave. Carbon fibre has an excellent weight to stiffness ratio, but failure can be instantaneous and unexpected. 'Kevlar', a commercial brand name for aramid fibres is also structurally stiff, but will flex and stretch before failure, making a composite weave for kayak applications ideal. The composite can be hollow shelled, or an inner foam core (usually a urethane) for added strength. There are a number of ways composites can be manufactured, but components are generally more expensive than the aluminium alternative, depending on the method used, but provides considerably more freedom in the way they can be manipulated into an organic form.

9.6 Design Criteria Extended

Effectiveness at overcome the barriers to kayaking

Primary Lifestyle Factors	Secondary Factors	
Performance	Safety	No compromise within design decisions, the kayaks must be safe from collapse, water egress and capsize.
	Stability	The kayak must be stable as it relates to safety, but also skill levels. It must remain stable in all weather conditions.
	Adaptability	This must adjust to the individual in terms of comfort and the correct ergonomics for paddling. It should also go further to compliment stability.
	Speed	Not an explicit need, but certainly important otherwise it may alienate more performance focused kayakers. This should also compliment stability but not jeopardise safety, as more stable kayaks are generally slower.
Dwelling	Storage	Highly important, the kayak must enable people to store the kayak in any dwelling they reside, or even outside if necessary.
	Pack-down Size	This directly affects where a kayak can be stored, but also crosses over with transport systems.
Portability	Weight	Fundamental to any transforming kayak, not a new goal in terms of transforming kayak, but it must be easily lifted and carried, or even put on the roof as directed by user comments.
	Transport Systems	This relates to all types of public and personal transport. The kayak must be able to be carried and stored on any form of transport, this also means walking and is directly affected by pack-down size and weight.
Time	Integration	A significant directive as a consequence of the research findings, the kayak system should fully integrate, leaving no parts for assembly that can be lost, or misinterpreted.
	Setup	A direct result of integration, but should encompass the significant points of interaction associated with setting up and packing down.
	Trigger	Another significant directive as a consequence of research. The trigger must be the central point for all transformation, the trigger should be simple to activate and afford an understanding of semantics.
	Semantics	This relates to the points of interaction, avoids confusion and setup time. Clever semantics help to categorise components, and lessens any unknowns, reducing the learning curve.
Manufacturing	Materials	There is no directive for which materials should be used, however they should not be hostile to the environment or people. Materials can be new or existing and should be relevant to the manufacturing methods and a water environment. The materials should reflect the intended design aesthetic.
	Cost	An obvious directive, although research findings ranked price point lower in necessity, it should still reflect the means of a range of lifestyles in terms of affordability. This could mean variations in material and manufacturing models covering different ends of the price spectrum.
	Methods	Although not at the forefront within an exploratory project, it does require thought on how the kayaks could be fabricated. This crosses into cost and materials and also the imagined business model. The methods may require new methods or combine/hack others.
	Aesthetic	Not a direct result of manufacturing but instead encompasses all primary and secondary factors. The aesthetic is expected to develop within the design and will be influenced by internal and external stimuli. The only real directive is it must represent many of the secondary factors i.e. it should look safe and performance oriented.

10.0 Bibliography

The following bibliography contains works of interest to the exegesis subject matter. The works are displayed under headings that relate to the categories and can be used as a reading list for further interest.

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